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TREASURY DEPARTMENT
UNITED STATES PUBLIC HEALTH SERVICE

PUBLIC HEALTH BULLETIN No. 106

FEBRUARY, 1920

STUDIES IN INDUSTRIAL PHYSIOLOGY: FATIGUE IN RELATION TO WORKING CAPACITY

COMPARISON OF AN EIGHT-HOUR PLANT AND A TEN-HOUR PLANT

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Special Expert, U. S. P. H. S.
and
MARY D. HOPKINS
Scientific Assistant, U. S. P. H. S.
on an
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Under the general direction of
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NOTE.

The present report is the first of a series to be published by the United States Public Health Service dealing with the problems of industrial working capacity. It is based on an intensive investigation of two factories, begun in 1917, under stress of war and still in progress at the present time. The investigation has been under the general direction of Prof. Frederic S. Lee. Dr. P. S. Florence as chief investigator in the field has been responsible for the material collected and has acted as statistician. Preliminary findings from still unpublished parts of the investigation made by Drs. Florence, A. H. Ryan, and E. G. Martin are included in this report in so far as they bear upon the subjects under discussion and are acknowledged on the appropriate pages. All charts and tables in the report were submitted to Prof. R. E. Chaddock, associate professor of statistics at Columbia University, and for his valuable criticism special thanks are due. The presentation of the material and the writing of the text of the report have been the work of Miss Josephine Goldmark and Miss Mary D. Hopkins. The Committee on Industrial Fatigue of the Council of National Defense acted in an advisory capacity in the course of the investigation.

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Ella C. Boyer	do	Sept. 20, 1918	
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[2] Services discontinued Sept. 7, 1917.

[3] Reappointed Mar. 8, 1919.

[4] Services discontinued Apr. 21, 1918.

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CHAPTER 1.

INTRODUCTORY.

With the entrance of the United States into the war the old problems of industry and labor suddenly changed. Industrial working capacity ceased abruptly to be a private concern; production became a public interest of the first consequence. In the face of a struggle of unknown length, the conditions and hours of industrial employment were recognized as no longer matters of private contract between workers and employers, but were newly envisaged as problems of national scope and concern. To attain maximum production without prejudice to national vigor—this was the new and enlarging demand of the time. But, on the other hand, the instant need of supplies awoke the instinct to spurt, to put on pressure, which has always been associated with the desire for quick returns. In many quarters the lessons of history and experience went for naught and the demand was raised for immediately lengthened hours of labor.[1]

Under such circumstances and with a view to contributing to the solution of these vexed problems of industry, an investigation into certain industrial conditions was begun in July, 1917, by the Federal Public Health Service in conjunction with the Committee on Industrial Fatigue of the Council of National Defense and the Committee on Fatigue in Industrial Pursuits of the National Research Council. The present report gives the first findings of the investigation which is still in progress. In peace as in war, working capacity is still a national concern. Its study should serve now not an emergency but the higher ideals of peace, the permanent industrial welfare and happiness of the Nation. If such a study of work is to be fruitful, it must be pursued as a science; and to such a science the results of the present investigation are offered as a definite, if limited, contribution.

THE STUDY OF FATIGUE.

More than a half century ago the study of fatigue was begun in the laboratories. The subject deals, in its essence, with the primary functions of life itself, with the metabolic processes by which lifeless matter is knit up into the fiber of the human body to assume living properties and is again, when used, expelled. In this study many interrelated chemical and physical problems of physiology and complex problems of psychology have been encountered. After 50 years of experimentation the controversial aspects of the subject are still many; the problems pressing for solution still increase as analysis of the phenomena of fatigue and recovery becomes finer.

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[1] For suspension or modification of various laws limiting the hours of labor see United States Bureau of Labor Statistics, Monthly Labor Review, May, 1917, p. 660; July, 1917, p, 55; September, 1918, pp. 266-270.

It is less than a decade since the study of fatigue broadened to include researches into men's working capacity in industry, upon which depends the economic production of the world and the satisfaction of its material needs. The initial studies of so-called "industrial fatigue", or the fatigue of industrial workers, centered upon general investigations of the health and attendance of employees, count of output and of accidents, and some attempts at laboratory measurements of fatigue, transferred into the factory.[1]

SCOPE OF THE PRESENT STUDY.

The present report deals primarily with the study of two objective tests of working capacity among factory employees, working under normal factory conditions, namely, the variations in actual hourly output and the variations in hourly incidence of accidents in two factories running, respectively, under an 8-hour and a 10-hour schedule. The difference in work at these two plants is further illustrated by a study of time lost at each factory, as shown by direct observation and by records of power consumption. An examination of labor turnover by departments at both plants furnishes statistical evidence of the relation of physical environment to the stability of the labor force. A study of recesses shows their effect on production. A preliminary statement of extended researches into the phenomenon of rhythm in industrial work now being carried on by Dr. P. S. Florence and Dr. A. H. Ryan closes the report.

The results of two laboratory methods of testing fatigue, the Ryan vascular skin reaction test and the Martin muscle test, will be fully reported in later publications and are only referred to here. The conclusions reached on all topics included in this report are given in summary form at the end of the introductory chapter.

THE FIELD.

Two factories were chosen as the field of investigation, each a huge industrial establishment prominent in the metal-working industry. One operated 22 hours in the 24 under the two-shift system, 10 hours by day and 12 by night. The other operated on three shifts of 8 hours each. These factories will be referred to in the report as the 10-hour plant and the 8-hour plant, respectively.

---

[1] See, for instance, British Ministry of Munitions: Health of Munition Workers Committee. Memoranda 1, 4, 5, 7, 8, 10, 12, 15, 16, 18, 20, 21; Interim Report and Final Report, 1914-1918. British Home Office, Second Interim Report, Investigation of Industrial Fatigue, A. F. Stanley Kent, professor of physiology, University of Bristol, 1916.

The investigation of the 10-hour plant covered two periods, one of 8 weeks, from July 17, 1917, to September 8, 1917; and a second period of two years, beginning in December, 1917, and still in process. The investigation of the 8-hour plant covered a period of 6 months, from September, 1917, to March, 1918.

These factories used essentially the same machinery and processes of the metal-working industry, though the immediate product was not the same in the two establishments at the time of investigation. The 10-hour plant was then largely engaged in the making of munitions; the 8-hour plant had not yet entered upon the war work to which its immense resources were later turned.

Most of the processes intensively studied at the 10-hour plant were those involved in the making of brass fuses for 3-inch shells. This type of fuse is about 4 inches long and 3 inches in diameter, a delicately balanced mechanism composed, roughly, of top cap, rings, body, and bottom closing screw, its inner recesses charged with powder. Of such fuses the plant daily turned out some 20,000, sealed in containers and ready to be shipped elsewhere to be assembled with the shrapnel shells they complete.

The hours of labor at this factory were 10 hours daily, from 7 a. m. to 12 and from 1 to 6 p. m. Overtime ran from 6 to 9 p. m. The night shift worked full 12 hours from 6.20 p. m. to 6.40 a. m., with a break of 20 minutes at midnight.

The operations studied at the 8-hour plant were the characteristic processes in the manufacture of automobiles.

The force was divided into three 8-hour shifts, 61 per cent being on the morning shift, which worked from between 6 and 8 a. m. to between 2 and 4 p. m.; 31 per cent on the evening shift, which worked from between 2 and 4 p. m. to between 10 and 12 p. m.; and the small remaining proportion of 8 per cent on the night shift.

METHODS OF STUDY: OUTPUT.

For a full discussion of the technique of output study, the reader is referred to the detailed work of Dr. P. S. Florence, the first systematic attempt to standardize methods of investigating industrial fatigue.[1]

Here it suffices to state in brief the fundamental requisites for such an inquiry which have been met in the present study. In securing and recording the facts the observance of certain technical details is essential to obtaining exact and trustworthy results. Human working capacity, functioning through the neuro-muscular mechanism, is plainly no static or rigid thing, nor yet a regularly varying phenomenon, the changes of which are easily measured or computed. All the more important is it, therefore, to ascertain and scrupulously to fulfill the conditions under which the variations of this sensitive mechanism may most successfully be registered. Briefly stated, the investigator must seek so far as possible to isolate the factor of working capacity in order to exclude other influences which may affect production.

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[1] Use of Factory Statistics in the Investigation of Industrial Fatigue. A Manual for Field Research. Philip Sargant Florence. Columbia University Studies in History, etc. Longmans, Green & Co., New York, 1918.

CHOICE OF OPERATIONS FOR STUDY.

The operations chosen must have an output which can be counted or otherwise measured during the period of inquiry. To this requirement the manufacture amd assembling of single units or parts of units in the metal-working industry lends itself with special readiness. The different processes here studied in the manufacture of the fuse and of the automobile involve repetitive work of diverse types, yielding units of output easily measured by the investigator, or even mechanically registered on the machine in the process of work. Certain processes, even though yielding measurable units of production, are irrelevant to our study and have been deliberately omitted. Thus output of purely automatic machinery, such as screw machines, the speed of which is wholly independent of the operator, registers, it is clear, only "mechanical efficiency, not human capacity." In furnace processes such as brazing, and in certain forging operations, the human agent still exercises an important if not dominating control and the output, though, as we shall see, far more evenly maintained than in processes allowing a free play of man's working powers, yet registers characteristic variations.

METHODS OF RECORDING.

Prominent among the requirements for obtaining accurate data is the proper method of recording output. In calculating the rate of production per hour it is obviously unfair to count in time when, through no fault of the worker, no work is being performed. Time lost either for repairs, for lack of materials or power, or owing to late starting or early stopping (when independent of the worker) or irregular lunch periods, bears no relation to genuine variations in working capacity and should be considered involuntary. Such time, accordingly, should be separately noted by the investigator and allowance should be made therefor by the proper statistical methods of correcting the output figures.[1] Our tables have been uniformly corrected for such causes, that is, the rate of output is given as though there had been no interruption.

Time lost voluntarily by the workers, on the other hand, as in resting, talking, leaving the workroom, etc., is genuinely related to working capacity and hence legitimately affects the curve of output.

---

[1] See Florence, op. cit., p. 47.

CLASSIFICATION OF WORK BY PHYSIOLOGICAL REQUIREMENTS.

Obviously no influence more nearly affects working capacity than the kind of work done and the demands it makes on the human organism. By dividing operations into different grades of "heavy" and "light" work, recent British writers have made a first attempt roughly to classify operations according to their physiological requirements. In the present study this attempt at classification has been carried a step further. Work has been divided, in the first place, into handwork and machine work. Handwork has been divided into types more genuinely related to the demands made upon the neuro-muscular system, that is, into hand operations requiring chiefly muscular exertions and those demanding exertions of dexterity and skill. In machine work, the well-defined lathe type of machine operation, demanding both muscular effort and dexterity, has been differentiated from other machine processes of various kinds. Not only does this division give us characteristic curves for the different types of work, differing quantitatively if not qualitatively, but it enables us by averaging the several representative types to build up and compare representative curves of the two factories as wholes, which is one of the distinguishing features of this report.

THE USE OF AVERAGES.

In order to obtain representative curves of output either for the whole plant, or for types of work, or even for single operations, it is obviously necessary to take into account many single observations of individuals at work. Individual output varies each day with many inconstant factors, such as health, sleep, family anxieties, good or ill will, relations with fellow-workers and the like. Hence it is desirable to average many single observations of each individual and of many different individuals in order to obtain a composite figure which, as Dr. Florence says, shall be "representative of the results of normal conditions of bodily and mental health and of normal factory management." Our tables include figures based on many hundreds of observations and exclude all based on less than 32.[1]

In such representative figures chance variations are canceled. Losing the individual in the mass, we obtain a true collective picture, a composite whole instead of merely isolated examples of this or that output. The gain in securing general conclusions, not individual idiosyncrasies, is obvious; the disadvantages will be pointed out in a later section on the limitations of this study.

---

[1] Three operations, commutator loom, p. 32, ramming molds, p. 44, and motor assembly, p. 44, are apparent exceptions to this rule, but each observation covered a group of workers. In four other operations where the total number of observations was less than 32, special circumstances, such as the short duration of the work, made impossible a larger number of observations. In these cases particular care was exercised to make the record accurate. The worker was kept under continuous observation, output measured unit by unit, and waste time measured to a fifth of a minute.

ADVANTAGES OF THE MAXIMUM AS A STANDARD OF COMPARISON.

How our representative figures have been composed is described in detail in the chapter on output. Here it suffices to state in brief how and for what purpose we have deliberately departed from the procedure of other investigators.

After obtaining the average output of each operation for each hour as outlined above, we must for the sake of comparison reduce these figures for the various operations to some common denominator. We must choose a standard of comparison, and this we have done by expressing our hourly averages as variations not from the average hour, as is ordinarily done, but as variations from the *best* hour, as shown by the hour of maximum output.

For our preeminent interest is not in the worker's approximation to his average performance but in his approximation to his best. It is accordingly the maximum hour which we have made our standard of comparison, rating each other hour by its fall from the hour of highest efficiency.

It is true that the use of the maximum as a standard of comparison is open to certain statistical objections. A standard of comparison must obviously not be subject to deviations of an extreme or violent character, as a maximum may frequently be. It must offer some guaranty of a fair measure of stability. In the limitations of human working power such a guaranty is afforded in the present case. Spurts, may for brief intervals, occasion an extreme deviation, but since they do not in any operation last an entire hour, they do not raise any hour so greatly as to invalidate the use of the maximum as a standard.

That our output figures are not subject to high extremes and are sufficiently massed toward the maximum to permit its use as the standard of comparison is proved by the following figures. The total number of average hourly outputs contained in the tables of both plants (chapter 2) and represented in our text by the familiar term "index numbers" is 344. Grouped according to their variation from the maximum 100, the index numbers are distributed as follows:[1]

	Index numbers.
From 100 to 96	138
From 95 to 91	112
From 90 to 86	48
From 85 to 81	18
From 80 to 76	12
From 75 to 71	6
From 70 and below	9

---

[1] For explanation of one additional index number not included here because slightly over 100, see p. 28.

Thus a very high proportion, 73 per cent, of these hourly output figures is massed within ten points of maximum; the remaining 27 per cent tapers down to the index number 48. The maximum, then, affords a satisfactory statistical basis of hourly comparison. It does more, it also makes possible a practical comparison of the relative efficiency of each type of work and finally of the two plants.

Absolute output at the two plants can plainly not be compared. Different workers are employed; the processes, though comparable, are not the same; the product is diverse. Even the deviations from the average output at the two plants can not fairly be compared, as may be readily shown. In such an average the drop of a single hour, if great, may lower the general level so far as to make it wholly unrepresentative of the entire day's work, and thus prevent us from comparing the deviations hour by hour with similar deviations from a more representative average. This is the case at the 10-hour plant, where the depression of the average by the deep drop of the final hour to 80 invalidates a comparison of the hourly deviations with the wholly representative average of the 8-hour plant, which is based on hourly figures varying within narrow limits and a last hour falling only to 95.5. This lowering of the average by an exceptional hour gives a misleading height to the other hours that rise above it. At the 10-hour plant the average as a standard shows the output of the best hour to be 106.6; at the 8-hour plant it is only 103.5. This apparent superiority of the 10-hour plant, in direct contradiction of the facts elsewhere shown, is obviously due only to the depression of its standard of comparison. It is clear from this example that the unlikeness of the standards represented by the averages at the two plants must vitiate any comparison of factory with factory or type with type of work.[1]

We can not, then, properly compare either absolute output or deviations from average output at the two plants. What we can compare is the deviation of each plant from its own best standard; that is, the relative fall from maximum of each hour at each plant. In this comparison there is evidence, specific and convincing, of the superior efficiency of the 8-hour plant, an efficiency which lies primarily in its greater maintenance of its own best standard, its approximation to the hour of maximum production. In answer to the possible objection that this standard may be a low one, and that the so-called superior maintenance of output may be merely a consistent mediocrity, we shall show proof in later chapters that this factory works nearer to capacity than the 10-hour plant, that its efficiency reaches a higher plane, and that by approximating more closely to its own maximum, the performance of the 8-hour plant is constantly on a higher level.

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[1] The unsatisfactory character of the arithmetic mean as a standard of comparison in discussing distribution of output may lead us to consider whether some other average might not prove more suitable.

(Arithmetic mean = sum of the amounts recorded divided by number of records. Mode = amount which occurs most frequently on the record. Median = the amount indicated by the middle record when all records are listed in the order of magnitude.) But in so short a series of terms the mode can not be found, as the same figure is almost never repeated. In so short a series, again, the median is not customarily used; it would, moreover, be faultily representative by giving no indication of the extreme variation of a single hour, just as the arithmetic mean is faultily representative by being unduly affected by it.

RELATION OF OUTPUT TO COST OF PRODUCTION.

For the manufacturer this approximation to capacity is of the first consequence in relation to one of his chief considerations, the cost of production. In the hour of highest production, the proportion of overhead costs is obviously lowest, and it is kept low in proportion as efficiency is maintained. For every hour in which output drops below the maximum, many overhead charges remain the same as for hours of highest capacity. Regardless of the amount of work done, expenses for such items as the time wages of workers, foremen, instructors, and inspectors, the cost of power for lighting, heating, driving the shafting, repairs to buildings and fixtures, costs of the office force, advertising, etc., continue at the same level, and, as output fails, constitute an increasing loss. Failure to maintain output in any one department may also interrupt the flow of work throughout an entire establishment and involve serious delays in promptness of delivering the finished product. The maintenance of steady output from hour to hour is, therefore, essential to keeping down the cost of production and living up to schedule.

METHODS OF STUDY: ACCIDENTS.

USE OF THE MINIMUM AS A STANDARD OF COMPARISON.

In the study of accidents, as of output, we have made the best hour our standard of comparison. This "best" hour in relation to output is, as we have seen, the hour of maximum production, and our interest has lain in the approximation of each hour to this highest standard. In relation to accidents, on the other hand, the "best" hour is the opposite extreme, the hour in which the accident risk is lowest. It is accordingly the hour of minimum risk which we have here made the standard of comparison, rating each hour by its relative rise above the lowest.

USE OF ACCIDENT RISK, NOT NUMBER OF ACCIDENTS.

In order to use this basis of comparison, we must first, however, seek to establish what accident risk is, and here also we have departed from the procedure of other investigators by basing our conclusions not on the absolute number of accidents, that is, the total number of accidents occurring each hour, but on the relation of accidents to the output of corresponding hours, that is, the ratio showing risk *per unit of output*.[1] As we shall show in detail, the absolute number of accidents may be and indeed has in other studies been totally misleading. It has led, for instance, to the assumption that the frequently lower level of the accident curve in the afternoon means a decline of the hazard in the afternoon, when the curve of the accident-output ratio shows the risk to be steadily and sharply rising.

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[1] See pp. 98–100.

As a basis for conclusions regarding the causation of industrial accidents, the ratio is of special value. By enabling us to show the relative rise and fall of risk in relation to accidents, it reestablishes the part played by fatigue in causing accidents, which has been minimized or denied in recent publications.[1]

DIFFERENCES IN MANAGEMENT AT THE TWO PLANTS.

That these two factories are to be taken as wholly typical of the 8-and 10-hour systems under which they respectively operate, we do not contend. Undoubtedly the superior mechanical equipment, the standardized product and the perfected system of personnel management at the 8-hour plant contributes to the greater maintenance of its working efficiency. Undoubtedly also, a better management of labor might reduce lost time at the 10-hour plant. How far the relative degree of excellence in these departments of management stimulates, or is itself stimulated by, the reduction of the workday we have no means of gauging.

In other essentials of management, such as centralization of authority, cost-accounting system, planning department, invention of labor-saving devices and setting of piece-rates, the 10-hour plant ranks high among efficient competitors.

A statistical index of the relative degree of excellence in management which is independent of the duration of working hours, in which the 10-hour plant also shows its good standing, is the proportion of time lost by employees through avoidable absences.

Careful calculation shows that the avoidable absences at the 10-hour plant as indicated by two representative months amounted to 3.15 per cent of the total time studied.[2]

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[1] See Industrial Accidents, ch. 5, pp. 96–98.

[2] This figure is obtained as follows:

Representative months.	Number of employees.	Working days in months.	Total man days.	Man days absent.	Per cent of total man days absent.
August	13,467	27	363,555	18,977	5.22
September	13,273	24	318,552	14,902	4.67
Average for the 2 months					4.95

To this average several corrections must be made. The number of employees absent was counted at 8 a. m., and therefore included all those who were absent for the morning only as well as those who were absent all day. But some workers who were present in the morning left at noon and were absent in the afternoon. Hence a correction must be made for the excess of those absent in the afternoon only, over those absent in the morning only. This correction was found to amount to 0.70 per cent of the total normal time. Adding this to 4.95 per cent of time absent we obtain 5.65 per cent.

To obtain now the total avoidable lost time we may be guided by a careful examination of 200 absentees in representative departments for the same two months. It was found that 55 per cent of absences were not due to sickness and were, therefore, avoidable.

The avoidable absence at the 10-hour plant, therefore, amounts to 55 per cent of 5.65 per cent = 3.11 per cent of the total working time.

To this there must be further added time lost by tardiness in arriving at the factory between 7 and 8 o'clock, or 0.04 per cent of the total time. Hence the total avoidable absence at the 10-hour plant = 3.15 per cent of the total working time.

It is true that at the 8-hour plant the avoidable absences are even lower, amounting to 1.53 per cent of the total time studied.[1]

That the proportion of time lost by avoidable absence is low at both plants, arguing good management at both in regard to attendance of employees, is indicated by a comparison with statistics of attendance published by the British Health of Munition Workers Committee, quoted here for lack of other relevant American figures. The British report shows that the proportion of avoidable absence in representative factories amounted respectively to 1.9 per cent, 3.8 per cent, 9.4 per cent and 10.3 per cent of the total working time in the periods studied.[2]

Period of study.	Number of workers.	Sex.	Type of work.	Hours of labor per week.	Total time absent—	Avoidable time absent—
					In per cent of gross normal time.	
15 weeks	560	Men and women	Light	52½	6.6	[1] 1.85
22 weeks	1,200	Men	Heavy	48–61	[1] 9.7	[1] 3.8
1 week	21,250	Men and women	do	52⅗	13.7	9.4
8 weeks	200	Men	Very heavy	49–51½	[2] 14.3	[1] 10.3

[1] Average calculated; not given by Loveday.
[2] Loveday considers the figures on which this average is based overestimated.

According to important tests of efficiency, therefore, the management of the 10-hour plant holds its own, and the failure of working capacity among its employees in the last hours of the morning and afternoon spells, as compared to the sustained performance of the 8-hour workers in comparable hours, can not be dismissed as evidence purely of slack management.

DIFFERENCES INDEPENDENT OF MANAGEMENT.

Whatever the influence of the factor of management, it is unmistakable that, with the shorter hours at the 8-hour plant, the attack upon work differs radically from that at the 10-hour plant. The statistics speak for themselves. Yet in comment certain facts may be pointed out as illustrative of this difference. There is sharply contrasted to the failure of the 10-hour workers in the last hour before lunch the power and frequent habit of the 8-hour workers to spurt in the corresponding hour. Thus in two out of six lathe operations and in one of the four dexterous operations a spurt, combining with the slow development of practice, actually increases the rate of output just before the short lunch period. In two other lathe operations and in another of the dexterous type, the spurt so far counteracts the fall that the output is maintained at a practically even level.

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[1] The total absences amount to 6.11 per cent of the total force (see Table 34, p. 170). Of this, 75 per cent is caused by sickness (see Table 31, p. 158). Hence the total avoidable absence is 25 per cent of 6.11 per cent = 1.53 per cent. It is noteworthy that the figures showing percentages of absence due to sickness at the 8-hour plant are taken from factory records; those at the 10-hour plant from a careful study by a special investigator for the Public Health Service. It is probable that a similar study at the first factory would have lowered the unavoidable absence and hence raised the avoidable percentage quoted in the text.

[2] Health of Munition Workers Committee, Interim Report, 1917, p. 41. Causes and Conditions of Lost Time, T. Loveday. The table here given in the text is summarized from Tables III, II, IV, and VII of the British report.

This difference between the sustained concentration of the workers at the 8-hour plant and the declining capacity of those at the 10-hour plant is seen at its height on the 12-hour night shift, in the frank abandonment of work in the last hour, and its gradual subsidence several hours earlier.

That it is the greater length of hours rather than difference of management which accounts for lessened output at the 10-hour plant is strikingly evidenced by the contrast between the day and night shifts at this same factory. For here in the operation known as spin top cap, under identical management but running at night on a 12-hour instead of a 10-hour schedule, we have reactions on the part of the workers to the longer hours closely resembling their reactions to a 10-hour as compared to an 8-hour schedule; the almost automatic response to the 6-hour as compared to the 5-hour spell is a still greater decline of working power. [1]

But the most convincing objective proof of the difference in working power at the two plants is afforded by the two curves showing hourly distribution of accidents. As we shall see in a subsequent chapter, it has been suggested that the accident curve is distinguished from the curve of output in an important particular: it appears to respond more sensitively and more quickly to the onset of fatigue. For even while output is rising, and before fatigue is regisistered in any slackening of the speed of production, it may be indicated by a disproportionately great increase of inaccuracies or errors leading to accident. Now at the 8-hour plant the accident curve shows in its first spell practically no indication of fatigue, but follows more or less closely the fluctuations of production, rising with increased and falling with lessened output. At the 10-hour plant the steeper ascent of the accident curve indicates even in the first spell the incipient fatigue which is manifested while output is rising by a more rapid rise of accidents. Again in the afternoon spell of the 10-hour plant as compared with that of the 8-hour plant, the greater rise of accident risk shows the greater failure of working power. The absolute number of accidents declines, it is true, even with the 10-hour day; but so much greater is the fall of output than the drop of accidents that the ratio between the two, showing *risk per unit of output*, rises, thus indicating the influence of fatigue. Both these factories, it should be noted, are leaders in the safety-first movement; they are equally concerned with the reduction of accidents to the lowest possible terms. The earlier rise of accidents in the morning spell, as well as the greater rise of risk in the afternoon spell at the 10-hour plant, would seem, therefore, independent of differences in management to be in large part the automatic response to the longer schedule of hours.

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[1] For differences ascribed to the fact that work is performed at night instead of by day, see p. 147.

LIMITATIONS OF THE PRESENT STUDY.

It is obvious that complex human conditions do not admit of the controlled experiments of mechanical and laboratory research, in which variants can be deliberately excluded at will. While the two factories studied are representententative of the metal-working industry, and though comparable types of work and operations have been carefully chosen, allowance must yet be made for the inevitable differences existing between any two individual establishments. A brief description of the plants will make this clearer.

THE EIGHT-HOUR PLANT.

The 8-hour plant has borne a dominating part in the development of one of the great industrial centers of America. In the great automobile industry it is easily the leader, employing more than one-quarter of the factory operatives of the city in which its main plant is situated and putting out a large proportion of the total manufactured products. The plant stretches a half mile deep on a front of nearly a thousand feet. Its almost 100 departments cover already more than 88 acres of ground; three times as many more owned by the company guarantee space for a future long-continued expansion.

The labor force averaged throughout the period of study about 36,000 workers. The average age is about 32 years; less than 25 per cent are more than 40. The employees are in great part skilled and experienced men. The number of women employed at the plant is almost negligible; on September 1, 1917, those in the manufacturing departments constituted scarcely more than 1 per cent of the total force. A year later replacement of men by women was barely beginning. Scarcely 40 per cent of the operatives are American born. Among the foreigners some 63 nationalities are represented; the largest groups, Polish, Italian, Roumanian, and Canadian, constitute but half of them. As regards home life and habits, these workers are probably above the average in temperance, thrift, and general standards. Most of them, it is said, own their own homes. More than half of these operatives live from 4 to 6 miles from the factory and must come to their work by the surface lines. To come a distance of 5 miles takes about 45 minutes or, roughly, one and one-half hours per day. A system by which the shifts go to work in sections at fifteen-minute intervals goes far, however, to avoid overcrowding on the cars.

THE TEN-HOUR PLANT.

While the 8-hour plant was slightly reducing its labor force during the year under investigation, the history of the 10-hour plant was characteristic of the mushroom growth of war industries. This plant is one of the great metal-working establishments of the country. It affords an excellent example of the so-called vertical combination of industries by which, through a multitude of processes, the product is worked up from raw material to complete finish and turned out ready for shipment. Early in 1915 the firm became deeply involved in the making of munitions, and the manufacture of peace-time products was to some extent discontinued. By a deliberate policy of the management, construction of new buildings was for the most part kept well ahead of the space actually required. More than doubled in size between 1914 and 1918, the great establishment stretches lengthwise irregularly more than a mile through the city and crosswise a third as far. As striking as the physical expansion of the factory was the growth of employment during these years. Here, too, the workers average slightly over 30 years of age, and many foreign races are represented. From a pay roll of 3,600 in 1914, the working force in 1915 was more than doubled and at the end of 1917 had reached nearly 13,000. Of these 13,000 about one-quarter were women. This great expansion, compared to that of many other war plants, was a controlled and gradual growth, yet it took place with none but the most casual facilities for lodging and feeding this industrial army.

The large mill town where the plant is situated was not prepared to receive a great influx of new workers. There were no adequate housing facilities in the city. Profiteering in rents became so conspicuous as to warrant the appointment of a special commission of investigation by the governor of the State. No lunch rooms existed in connection with the plant or near it, and the congestion in lunch places and on the trolleys at the noon hour was intolerable. Not until September, 1918, was a cafeteria opened in connection with the plant, with accommodation for about 500 persons daily.

Thus, while the labor force of the two factories studied was recruited largely from the same general sources, and at each more than half of the employees were foreign born, yet marked differences existed in the conditions of the workers.

FURTHER DATA NEEDED.

Aside from the necessity of making allowances for these differences, we must indicate certain limitations in our data which emphasize the need of further study. In presenting this report an effort has been made to distinguish between those subjects in which the statistics prove certain definite conclusions, those in which the statistics show certain well-defined tendencies, and those in which the statistics are as yet inconclusive. Further investigation is needed along various lines only indicated in this first report.

1. NIGHT WORK.

While, for instance, the economic waste of the last two hours of the 12-hour night shift, as compared with the 10-hour day shift, has been established by showing the greater relative decline from maximum output at night, no conclusions have been reached as to the actual difference in efficiency of day and night workers. For such a comparison there is needed a study of the actual output of the same individuals working under the same schedule of hours by day and by night.

2. OVERTIME.

Owing to the irregularity of overtime at both plants, no consecutive study of this important feature of industry was made. Such an inquiry is urgently needed, showing not only the output of overtime hours, but the output of periods of employment immediately preceding and following. The effects of overtime can best be gauged by comparing the production of days before and after the introduction of extra hours. For the critical question is not only the effect of the increased hours at the time, but their effect, in the long run, on total production.

3. RECESS PERIODS.

Further investigation into the effects of recess periods is desirable. Obviously, as this report shows, individual variability must be expected in any system of recesses. Undoubtedly our statistics prove more conclusively than has been proved before that with the long workday the interruption of work is on the average more than compensated by the recuperation afforded by the recess. Further explanations should be sought for the fact that gains in rate of production may occur after the introduction of rest periods without increase in total daily production. The possibilities of refreshment to be gained from different kinds of recreation during the recess have never been adequately tested. A scientific study of recesses and of the proper facilities for recuperation during the interval of rest requires consideration not only of the nature of the work but of the race and temperaments of the workers. For Italians, for instance, the provision of music during the cessation of work might afford relief from concentrated attention to which native American or Irish workers would be indifferent. Certain obvious requisites for the recess period, such as change of posture, ventilation, exercises, have been variously introduced in different establishments. But the establishment of regular periods for rest is as yet too rare and too recent for the study of any finer adjustments to have been made.

4. PHYSICAL CONDITIONS OF WORK.

Influences on working capacity untouched in this study, yet undeniably important, are the physical conditions under which work is performed. Heat, cold, humidity, light, darkness—the various degrees of these ordinary factors of environment intimately affect men's working powers and call for as careful and minute observation as do the more abnormal factors such as poisons, gases, fumes, and smoke. No opportunity was offered in this investigation to relate these factors to the rate of output or of accident. Yet undoubtedly in any future science of work tasks will not be predicated without weighing the effect of these important elements, and where they can not be eliminated, allowing for them as inherent parts of the work, to be balanced by lessened exertion.

5. THE STUDY OF RHYTHM.

The relation of rhythm to industrial efficiency is another subject on which only preliminary findings are included in this report. The Public Health Service investigation now in progress into this intricate subject promises to yield fruitful conclusions in a new and hitherto untouched field.

6. STUDY OF INDIVIDUALS.

By basing our statistics and comparisons on the average fall from maximum, we have succeeded in obtaining pictures of the daily cycle of work in each process and type and in the two entire factories. With the inevitable subordination of the individual worker inherent in such a study, there is needed also a companion investigation of a wholly different nature: an investigation of individuals.

Mass statistics yield the general truths, the generalized conclusions on which a scientific study of work must be predicated. But for a complete statement they must be supplemented and interpreted by a knowledge of the individual men and women who compose the averages. Thus mass statistics show, for example, the relative level of efficiency at which the average worker at each of our two plants and in each type of work begins his task. Obviously individuals differ widely in their physiological preparedness for work in the morning, and in the level of fatigue reached at the close of the day. Such differences the physiological adaptation of work must ultimately take into account and seek to remedy; and such differences can be learned only by reverting from mass statistics to the study of individual men and women.

A study of output such as the present one, being limited in time, is obviously only a partial criterion of men's total working capacity and welfare. To gauge the maintenance of working capacity in the long run requires a broader study of the effects of industrial occupations upon individuals, a study initiated to-day by industrial medicine and nursing, and capable of far-reaching development.

What we need, then, to supplement our statistical data is a realization of the individual, not as the component of averages, nor yet as the lifeless machine, but as himself a producer and creator of values however minute. As such his creative powers take on a new excellence and intrinsic worth, so that all that hinders them, all that makes for waste of power, waste of human energies, such as the records of muscular overfatigue in the operation of ramming molds or the excessive fall of output in the heavy work known as planish seat, shall be condemned on the evidence of the figures.

For what is the value of such an attempt as this to define work according to its physiological demands? It is not a study in vacuo; not an academic inquiry into the nature of this or that type; not prompted by mere interest in industrial efficiency, narrowly conceived with a sole eye to immediate output. Such a classification of work contemplates something more fundamental. When completed and carried far beyond these first beginnings it should point the way to new methods in the apportioning of work, so that for instance, heavy labor which can not be replaced by mechanical invention shall be lessened by diversifying and rotating of occupation; so that workers who must be employed on processes where it is impossible to substitute mechanical for human effort, shall work under such conditions of rotation and change as to avoid premature failure of the working powers and the stunting of human development, as compared with men or women engaged in work in which such tendencies are absent.

The physiological analysis of work foreshadows new methods of training, new calculations of industrial stresses, new adaptations of the worker to his job, a new emphasis on selection of work.

It is impossible that industrial processes can ever be wholly mechanical. Back of the mechanical perfections there is need of the human eye and human direction. To enlist the interest and cooperation of the worker, therefore, is one of the great problems of industry. Yet industrial advance lies in the direction of greater, not less, subdividing and specializing, entailing further restriction of individual effort along narrowing lines. It is for this reason, from the point of view of production itself, in the large sense, as a developing science of work, that so great a value necessarily attaches to means by which the workers can be made to feel their value to industry and to the Nation as creative and producing units. Thus, for instance, farseeing employers have found that by providing for the participation of the workers in the conduct of industry their interest has been so stimulated as to release their energies along new channels.[1]

In connection with this subject, in its final report, the British Health of Munition Workers Committee states as follows: "If industry be indeed a national service, the object of those engaged in it is the good of the community as a whole, and the worker should have a fair and legitimate share in the responsibility of the transaction." With this newer conception of the workers' creative share in manufacture, industry will necessarily become one of the most important contributors to the ends of democracy. It is evident that methods in industry which tend to reduce men to the level of its lifeless mechanisms, and which exhibit less solicitude for their welfare than for the machines themselves, reduce them also below the level of decent citizenship.

On the other hand, if industry treats its men as sharers in a common enterprise and thus takes them into partnership it will in the very course of production be performing a greater function; it will, by the same token, be fitting men for the best uses of leisure, for taking their share in the greater democracy of the State.

Such larger considerations are not alien to the intensive inquiry which is the special subject of this report. The era of general impressionistic presentation of economic and social problems has done its work. That complexities of maladjustment exist, that all the ingenuity of human invention must be expended upon them, need no longer be contended. The new era opening for social and economic progress is now to bring to bear upon these intricate problems the finest powers of science, focussing upon the several elements, among which health is of first importance, integrating them and relating them to a large view of human society.

To humanize working conditions, to reassert the value of the individual, to study all ways of releasing in work the best energies of the worker instead of as now so prodigally wasting them, this should be the practical rôle of science in industry. And it is as a contribution to this new era of intensive study devoted to large ends that this report has been aimed.

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[1] See, for instance, United States Shipping Board Emergency Fleet Corporation, Industrial Relations Division, Philadelphia, April, 1919. Works Committees and Joint Industrial Councils. Michigan Manufacturing and Financial Record, Feb. 22, 1919. Why We Placed Our Workers in the Majority on Our Board of Directors. David A. Brown, president, General Ice Delivery Co., Detroit.

SUMMARY OF CONCLUSIONS.

I. Relative Efficiency of the Eight-Hour and the Ten-Hour Systems as in Operation at the Two Plants Studied.

A comparison of the 8-hour and 10-hour systems leads to the conclusion that the 8-hour system is the more efficient. This is evidenced by—

1. *Maintenance of output.*—The day shift: The outstanding feature of the 8-hour system is steady maintenance of output. The outstanding feature of the 10-hour system is the decline of output.

2. *Lost time.*—Under the 8-hour system work with almost full power begins and ends approximately on schedule, and lost time is reduced to a minimum. Under the 10-hour system work ceases regularly before the end of the spell and lost time is frequent.

3. *Stereotyped or restricted output.*—Under the 10-hour system artificial limitation of output is widely prevalent. Under the 8-hour system output varies more nearly according to individual capacity.

4. *Industrial accidents.*—(*a*) In the absence of fatigue, accidents vary directly with speed of production owing to increased exposure to risk.

(*b*) The breaking up of this regular variation by fatigue is indicated by—

- (1) The rise of accidents with the fall of output;
- (2) The disproportionate rise of accidents with the rise of output and the absence of a proportionate fall of accidents with the fall of output in the final hours of the day.

(*c*) The importance of fatigue in the causation of accidents is emphasized by the fact that the higher accident risk accompanies the deeper decline of working capacity—

- (1) In the second spell as compared with the first;
- (2) In muscular work as compared with dexterous and machine work;
- (3) At the 10-hour plant as compared with the 8-hour plant.

(*d*) The level of the accident rate varies inversely with the experience of the workers.

II. General Data.

1. *The night shift.*—Under the 10-hour system a 12-hour night shift is the rule. The chief characteristics of the 12-hour night shift are the abrupt fall of output in the last two hours and the progressive slowing in rate of production during the night.

2. *Labor turnover.*—(*a*) Labor turnover is directly associated with distasteful working conditions, such as long hours, low wages, and undesirable physical surroundings. It is lowered by systematic effort to improve conditions and fit the workers to their jobs.

(*b*) Turnover is highest among new employees.

3. *The effects of rest.*—(*a*) Recesses.

(1) *Effect on total daily production.*—Varying results follow the introduction of 10-minute recesses in the middle of the morning and afternoon spells. With some workers the loss of time is not made good and output falls; with others the acceleration due to the recess exactly balances the loss of time and output remains the same. In 12 out of 16 operations studied there was an average increase of production after the introduction of recesses. In operations having two periods of trial the gain in the second period was, on the average, five times greater than in the first.

(2) *Effect on hourly rate of production.*—Recesses usually lead to a rise in the rate of production in the hours immediately following as compared with the hours immediately preceding the recess.

(*b*) Holidays.—Holidays cause an increase in output.

4. *Rhythm in industry.*—In certain machine operations, notably in lathe work, output is maintained at an even level, instead of falling in the final hours of work. This peculiarity may in large part be explained by the phenomenon of rhythm to which lathe work is highly amenable.

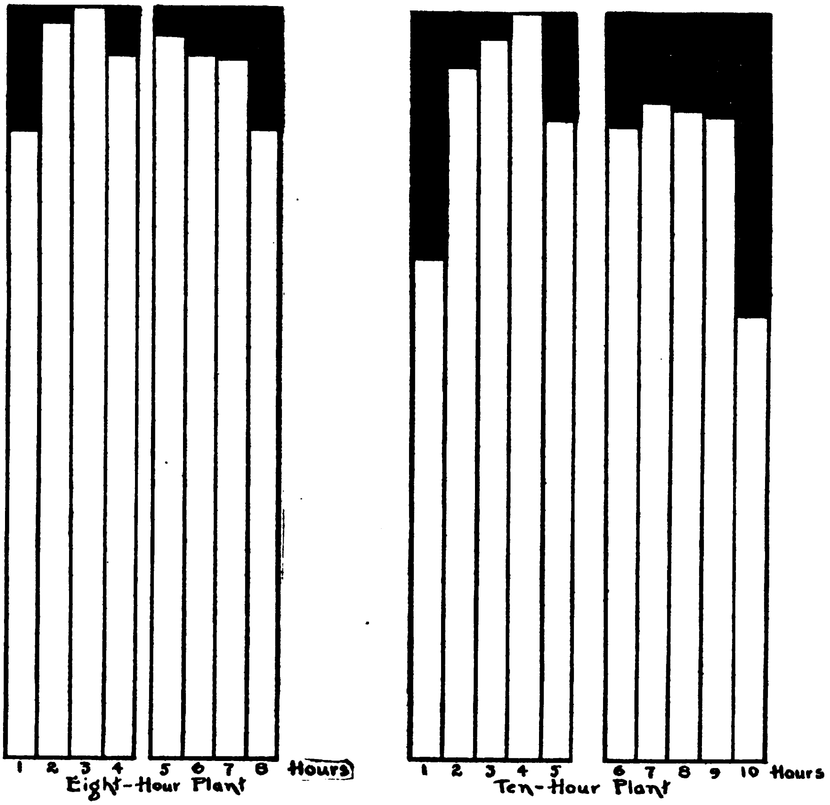
CHAPTER 2.

THE MAINTENANCE OF OUTPUT IN THE DAY SHIFT.

The conspicuous feature of the 8-hour plant is its steady maintenance of output in contrast to the fluctuations of output at the 10-hour plant.

This contrast is shown by the representative curves for the entire factories which are here presented in simplified form. The top line of the diagram represents the maximum hourly production for each factory. The relative hourly approximation to maximum production is indicated by the black and white areas on the charts. The black space in each column shows how far each hour falls short of maximum efficiency. The smaller black area for the 8-hour plant in contrast with the larger black area for the 10-hour plant shows the closer approximation at the former.

COMPARATIVE MAINTENANCE OF OUTPUT AT THE TWO FACTORIES.[1]



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[1] For complete chart and figures on which this simplified representation of the two factories is based, see p. 74.

The figures of output presented in the following study were obtained partly by continuous observation and hourly count by the Public Health Service investigators in the factories throughout the day, partly from the figures and the records of the foremen properly supervised and checked. The results of the observations are here presented in the form of statistical tables and corresponding charts.

It was obviously impossible to observe and record output in all the manifold processes which enter into the manufacture of so complex a mechanism as an automobile or which compose the activities of a great metal-working establishment. Some division into types, therefore, was essential. Following Florence's plan, the operations were classified under four main heads: Dexterous handwork; muscular handwork; machine work on lathes; and miscellaneous machine work. This classification is admittedly more or less rough; in some of the types, as is pointed out in the text, the operations grouped together are not all strictly homogeneous; yet they are all properly representative of their types, owing either to the common physical requirements they make of the workers or to use of the same general type of machine. Under each type of work various representative operations were studied.

EXPLANATION OF THE TABLES AND CHARTS.

The figures given in the tables for each operation represent its average output per worker, or group of workers, for each hour of the day. To obtain these figures, the total output for each hour recorded for a given number of workers during a given number of days was divided by the product of the number of days and the number of individual workers or groups of workers observed.

To obtain representative figures for the average hourly output of each of the four main types of work, it was clearly improper merely to add the figures for man-hour or group-hour output as they stand. since the products of the operations are wholly different and the number of pieces produced per man per hour or per group per hour varies widely. To give equal weight to each operation in the total output it was necessary, therefore, first to reduce the man-hour or group-hour outputs to a common measure. To secure this common measure, we have represented the maximum hour's output[1] in each operation by the "index number" 100, and the outputs, or index numbers, of the other hours as percentages of the maximum output. Thus, for instance, in Table 1, pages 32–33, the output (691) of the third hour under rivet press, being the highest for the day, is represented as 100; the index number for the first hour is $\frac{630}{691} \times 100 = 91.2$; that for the second hour is $\frac{663}{691} \times 100 = 95.9$, etc. We thus obtain for each of the several operations index numbers or percentages representing the comparative variation from maximum output for each hour of the day. By averaging these numbers for the several operations we obtain for each hour the representative variation from maximum output for an entire group of operations. These average index numbers or percentages are given in the last line of each table.

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[1] Where the maximum hour's output represents the actual work of a period of less than three-fourths hour "corrected" to the hourly basis it has not been designated as 100 or used as a basis of index numbers. See Table 7, p. 67, where a maximum resulting from one-half hour's prorated output is represented not by 100 but by 100.6.

For purposes of comparison the averages for the morning and the afternoon spells and for the whole day are given in the tables and charts.

The extreme right-hand column in the tables, showing the ratio between the work of the two spells, expresses briefly by another method the relative efficiencies of the morning and the afternoon. If the ratio is above 100, the output has been rising; if below 100, it has been falling.

GENERAL CHARACTER OF THE CURVES.

When presented in graphic form, the figures of output in the tables show curves of various shapes differing according to the kind of work done and the effort expended by the workers. Thus, for example, work requiring attention and dexterity presents one general type of curve; heavy work requiring muscular exertion, another; and so on. Various typical curves may be thus distinguished.

The main features common to all these curves are the rise of output from the level of the first hour of work toward maximum and the fall of output at the end of each working spell and the end of each shift.

The rise in the curve is commonly ascribed to the effect of practice, which is probably the expression of improved neuromuscular coordination. This influence of practice is shown not only in the marked increase in working power during and after the first hour of work of each spell but it affects also, as we shall see, the relative level of the output of the hours after any lunch interval as compared with the hour preceding.

The fall in the curve, familiar from previous studies, and especially prominent in recent wartime experience, is generally ascribed in part to the development of fatigue during the course of activity. A certain degree of parallelism exists between this decline of working capacity and a similar diminution in lifting power of electrically stimulated muscle, as fatigue develops, involving physical and chemical changes within the muscle.[1] The fall of the output curves may thus in a broad sense be held due in a considerable part to the same basic causes which underlie the fatigue of isolated muscle, but it is well recognized that the fall is not due to such fatigue alone. In the great complexity of man's psychophysical constitution, reacting to the most diverse stimuli, other remoter manifestations of fatigue, psychological and nervous, are operative in contributing to the fall of production. In our study of lost time, of the stereotyping or limitation of output, and of accidents, these other manifestations are discussed at length.

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[1] See The Human Machine and Industrial Efficiency, Frederic S. Lee. Longmans, Green & Co., New York, 1918, p. 13.

Practice and fatigue are thus opposing forces, the one carrying up working capacity, the other dragging it down. "Obviously," says Dr. Myers,[1] "fatigue and practice work in opposite directions, and the work curve obtained is the resultant of these factors. Generally speaking, the influence of practice is great at first, but smaller later, whereas the influence of fatigue is small at first but greater later." Thus the shape of the curve will be determined, among other things, by the relative influence of each of these two factors.

Another important determinant of the output curve is recuperation arising from rest and food. The improvement in output that frequently occurs just after the noon interval indicates the effect of such recuperation. This is especially marked in operations that demand a great exertion of muscular strength. In other operations, however, especially those in which coordination and practice play a large part, the first hour after the noon break frequently registers a fall, not a rise, of output. Here recuperation tends to raise working capacity while loss of practice tends to lower it. Thus loss of practice masks for a time the benefit of the break in affording rest and recuperation. The level of the curve immediately following the break is thus probably determined in chief part by the relative strength of these two factors.

Myers has called attention to another factor in the curve of work which "can not be explained merely by loss of practice and fatigue." "After the resumption of work," he says, "a certain period is required for getting under way. The human machine has 'grown cold;' it must needs be 'warmed up.' "[2]

This factor has been termed "incitement."

Still another factor which influences the curve is the "spurt," which in response to some special interest or emotion on the part of the worker produces sudden increases at irregular times.

THE COMPOSITE GROUP CURVES.

It is clear that while each individual operation reaches a maximum of 100 at some hour of the day, these maxima, owing to the differences between operations in the same group, do not often fall at the same hour. Hence the composite curve of a group, based on the curves of the separate operations, can rarely if ever reach 100, the limit of possible efficiency. In other words, the highest possible production of all the operations in a group is rarely found concentrated in a single hour. In point of fact, this takes place in one group only, in lathe work at the 10-hour plant. But it is obvious that if the maxima within a group coincide, their coincidence does not raise the total output for the day, any more than their dispersion would, since a higher rise of the peak of production in one hour is balanced by deeper falls in other hours, so that the total for the day remains the same.

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[1] Present-Day Applications of Psychology, Charles S. Myers. Methuen & Co., London, 1918, p. 10.

[2] Op. cit., p. 12.

The dark shaded area in the graphic curves represents the difference between the highest hour of the group and 100, the highest possible production.

DEXTEROUS HANDWORK.

1. THE EIGHT-HOUR PLANT.

Studies of dexterous handwork at the 8-hour plant were made in four operations. The results of the observations are presented in Table 1 and chart 1.

It will be seen in this composite curve that output is low only in the first and last hours of the day. There is a marked rise in efficiency in the second hour of the morning spell, as the workers warm up to their tasks, and attention and coordination improve; the maximum output of the day is reached in the third; and the fourth continues high. After the lunch interval, which averages half an hour at the 8-hour plant,[1] practice is to some degree lost and working capacity is at a lower level in the first hour; it increases again slightly, and thereafter maintains itself without any further decline during the afternoon until the typical drop is shown in the last hour. The fall of output in the last hour below that of the maximum hour averages for the type 9.3 points. The average for the afternoon is 2.3 points lower than for the morning.

In this group two of the four operations reach their maximum in the third hour; at this hour, accordingly, the composite curve reaches its highest point, 98.2, only 1.8 per cent below 100. This difference (1.8 per cent) is represented by the dark shaded area on the chart.

In the table representing the individual operations, the maximum hour is represented by 100. As stated above, some variations from the composite curve are shown by the curves of the individual processes that make up the type. In this group, for example, while one operation, roll coil, follows exactly the form of the composite curve, rivet press parallels it in the morning, but varies somewhat in the afternoon; magneto taping reaches its maximum an hour earlier, rises slightly instead of falling after the noon break, but fails thereafter to maintain production; commutator loom starts with lower efficiency, reaches maximum in the fourth instead of the third hour, and in the afternoon shows a steady fall, instead of the even output and slighter final drop of the type as a whole. Yet all these operations are typical of dexterous handwork in their demand on skill and attention.

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[1] The lunch interval at the 8-hour plant is in some operations ¼ hour, in others ½ hour, and in still others ¾ hour.

TABLE 1.—*Eight-hour plant,*

Operation.	Number of observations.	Starting time of shift.	Period of study.	(a) Number of units; (b) Index numbers.[1]	Average output observed each working hour.	
					First.	Second.
Rivet press	64	7.30 a. m.	Oct. 13–30	(a)	630	663
				(b)	**91.2**	**95.9**
Roll coil	86	...do	....do	(a)	246	253
				(b)	**96.1**	**98.8**
Magneto taping	63	...do	July 23–Sept. 24	(a)	435	471
				(b)	**92.4**	**100**
Commutator loom	15	...do	Oct. 23–Nov. 15	(a)	763	871
				(b)	**85.2**	**97.2**
Average index numbers					**91.2**	**98.0**

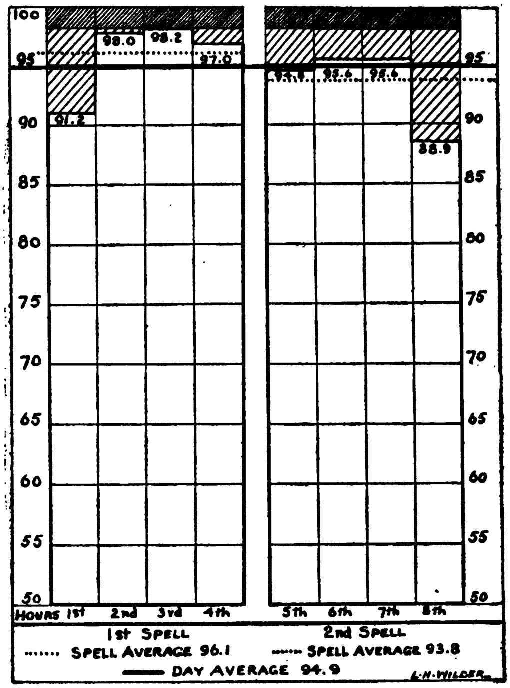
[1] Index number = percentage variation from maximum; maximum = 100.
[2] Period of ¾ of an hour; actual output multiplied by 4/3.
[3] Period of 1¼ hours; actual output divided by 5/4.

dexterous handwork.

Average output observed each working hour.									Ratio of spells—second spell to first spell (in per cent).
Third.	Fourth.	Average for spell.	Fifth.	Sixth.	Seventh.	Eighth.	Average for spell.	Average for day.	
691	[2] 654	660	653	642	651	[3] 616	641	650	
100	**94.6**	**95.5**	**94.5**	**92.9**	**94.2**	**89.1**	**92.8**	**94.1**	**97**
256	[2] 252	252	236	252	253	[3] 226	242	247	
100	**98.4**	**98.4**	**92.2**	**98.4**	**98.8**	**88.3**	**94.5**	**96.5**	**96**
451	[2] 448	451	456	455	452	[3] 431	449	450	
95.7	**95.1**	**95.7**	**96.8**	**96.6**	**96.0**	**91.5**	**95.3**	**95.5**	**99**
871	[2] 896	850	856	845	835	[3] 776	828	839	
97.2	**100**	**94.9**	**95.5**	**94.3**	**93.2**	**86.6**	**92.4**	**93.6**	**97**
98.2	**97.0**	**96.1**	**94.8**	**95.6**	**95.6**	**88.9**	**93.8**	**94.9**	**97**

CHART 1. *Index numbers showing percentage variations of hourly output from limit of possible efficiency.*

EIGHT-HOUR PLANT—DEXTEROUS HANDWORK TYPE.



LIMIT OF POSSIBLE EFFICIENCY (100) = HIGHEST OUTPUT ATTAINABLE IF ALL OPERATIONS COMPOSING GROUP REACH MAXIMUM AT SAME HOUR.

▨ = DIFFERENCE BETWEEN LIMIT OF POSSIBLE EFFICIENCY AND ACTUAL MAXIMUM HOUR'S OUTPUT FOR GROUP

▧ = DIFFERENCE BETWEEN MAXIMUM OUTPUT AND OUTPUT OF EACH HOUR.

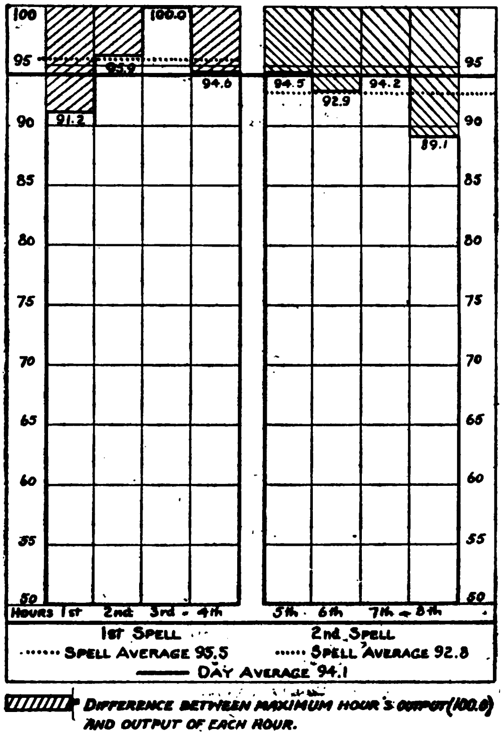
(a) Rivet Press.

A good illustration of the nature of these dexterous processes is given by the operation called rivet press (chart 2). Its object is to fasten a tiny rivet into a small T-shaped "spacer," one of the many small pieces of brass that save the wear and tear of parts in the finished car. This is an operation requiring for its regular output of some five thousand a day, dexterity, speed, and continuous attention.

Sitting before a small hand press about 15 inches high, the operator picks up one of the tiny rivets and places it bolt upward on the press platform. Then he takes the spacer, slips the foot of the T into a small iron holder in his right hand, lays it over the rivet, fitting the small hole at the cross of the T exactly over the bolt, and pulls down the press handle to hammer the bolt in. He slips the riveted spacer from the holder, throws it aside, takes another rivet and begins again.

CHART 2.—*Index numbers showing percentage variations of hourly output from maximum hour's output.*

EIGHT-HOUR PLANT—RIVET PRESS.



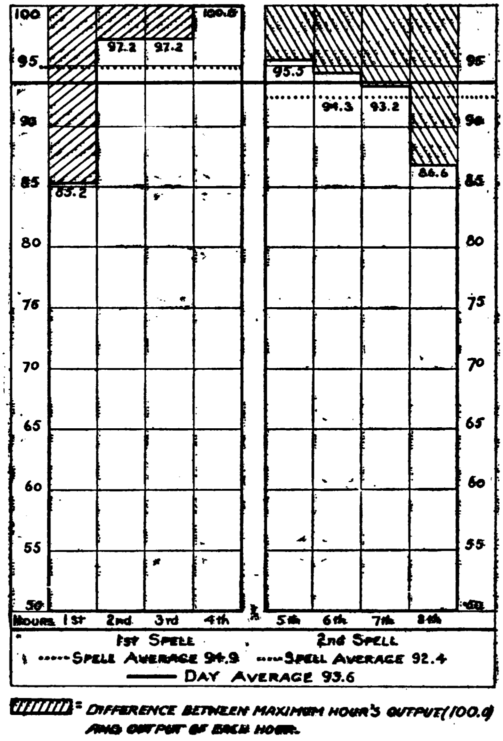
It has taken something less than six seconds, and this pace must be maintained for eight hours to make the usual output, an average of eleven per minute. According to the foreman's statement, it takes about two weeks for a new worker to "get up speed" in this work.

(b) Commutator Loom.

Another typical example of dexterous handwork, performed in a series of specialized operations by a large battery of 45 girls and men, is the so-called commutator loom process (chart 3), which consists in finishing the ends of the five magneto wires that are bound together to form the commutator wire or loom. These looms, or bundles of wires, are somewhat more than a yard long and as thick as a man's thumb. At each end the five insulated magneto wires, colored red, blue, green, black, and Scotch plaid, respectively, project for a few inches.

Chart 3.—*Index numbers showing percentage variations of hourly output from maximum hour's output.*

EIGHT-HOUR PLANT—COMMUTATOR LOOM.



Before a wide, moving conveyor a line of girls sit on high stools; at the end of the line one woman, the starter, feeds the conveyor, laying the looms crosswise into the grooves that hold them; the tips hang free over the edge. Each girl in the first group selects a bundle as it reaches her, and, without lifting the loom from the conveyor, inserts the wire tips rapidly one by one into the small hole of a clipping machine before her, and strips off the insulation, leaving the wires bare.

Further along the line are the girls who pinch or "string" on the brass "terminals" or contact ends. Each must insert the wire tip in a hole in the small brass clip or terminal, bend the wire tip back, and pinch the terminal over it. As no one girl can handle the five terminals in the time allowed by the conveyor, each one is responsible for a wire of one color in each one of the passing bundles. Thus, one girl finishes all the red magneto wires, another all the green, another all the blue, etc. This is the most taxing part of the entire process. Finger and thumb, tender at first, become callous with the constant bending and pinching; the effort to distinguish the moving colors and the need for rapid exactness in inserting the wire tips is exacting eye work.

Next in the process, a row of men with acid bottles and soldering irons fixed before them take the looms from the conveyors and solder the terminals to the wires. Last, at the end of the line, the inspector looks over the completed looms and throws aside any imperfect ones for refinishing.

For each monotonous detail of the process coordination must be close and attention unwavering. The demand on speed and skill is continuous; no process illustrates better the requirements of dexterous handwork.

2. THE TEN-HOUR PLANT.

Studies of dexterous handwork at the 10-hour plant were made in seven operations. The results are presented in Table 2 and chart 4.

The composite curve for this type exhibits the same general characteristics as at the 8-hour factory, but shows an earlier and much more marked decline. Here, also, the maximum output is reached in the third hour of the morning spell after a notable rise from practice, and the fourth hour continues high. But the effect of an additional fifth hour of work is shown in the greater decline of efficiency in this period, averaging 7.4 points from the maximum hour as against a fall of 1.2 points in the last period before lunch at the 8-hour plant. In the first hour after the noon break—a full hour at this plant—working capacity shows only a very slight loss. In the second hour it rises again slightly with practice, but sinks after a single hour, and the fall of the last hour of the 10-hour day is more than twice as great as that of the last hour of the 8-hour day—21.5 points against 9.3 points. The average for the afternoon is 6 points lower than for the morning, as against 2.3 points at the 8-hour plant. The superior stability of the 8-hour plant in this type of work is thus made strikingly evident.

Since five out of the seven operations composing this group reach their maximum of 100 in the third hour, it is natural that the highest point of the composite curve should fall only slightly (1.5) below 100.

Table 2.—*Ten-hour plant,*

Operation.	Number of observations.	Starting time of shift.	Period of study (days).	(a) Number of units; (b) Index numbers.[1]	Average output observed each working hour.		
					First.	Second.	Third.
Fuse assembly	70	7 a. m.	22	(a)	717	887	897
				(b)	**79.9**	**98.9**	**100.0**
Painting screw holes with lacquer.	58	7 do.	14	(a)	626	607	676
				(b)	**89.8**	**100.0**	**97.0**
Charging large buttons[2]	47	7 do.	10	(a)	6.392	6.587	6.752
				(b)	**94.7**	**97.6**	**100.0**
Charging medium buttons[2]	32	7 do.	11	(a)	4.563	4.676	4.924
				(b)	**92.7**	**95.0**	**100.0**
Charging small buttons[2]	105	7 do.	10	(a)	2.464	2.601	2.613
				(b)	**94.3**	**99.5**	**100.0**
Assemble cartridge clip	165	7 do.	23	(a)	27.56	31.23	32.05
				(b)	**86.0**	**97.4**	**100.0**
Solder body and collar of thong case	51	7 do.	7	(a)	135	152	151
				(b)	**82.8**	**93.8**	**92.6**
Average index numbers					**88.6**	**97.4**	**98.5**

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[1] Index number=percentage variation from maximum; maximum=100.

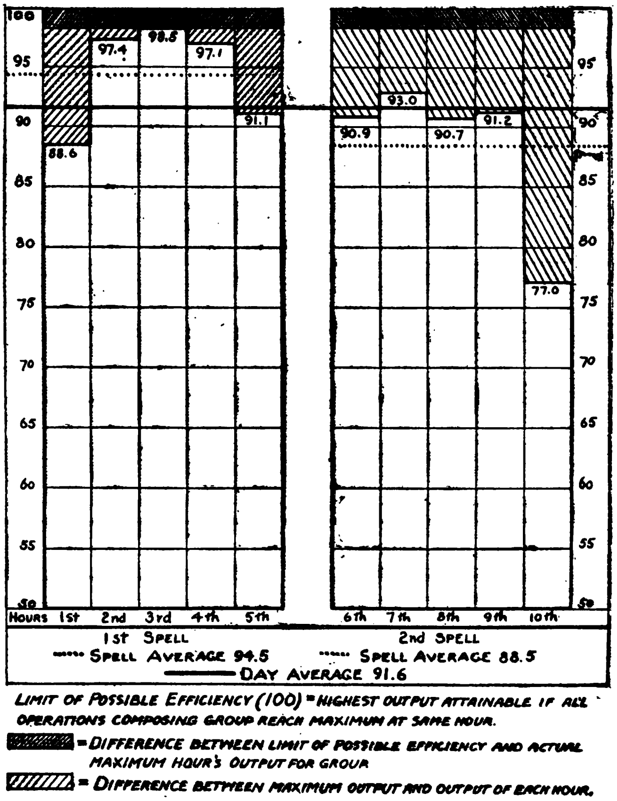
[2] Output given in pounds, not units.

dexterous handwork.

Average output observed each working hour.										Ratio of spells—second spell to first spell (in per cent).
Fourth.	Fifth.	Average for spell.	Sixth.	Seventh.	Eighth.	Ninth.	Tenth.	Average for spell.	Average. for day.	
885	813	840	754	837	831	819	754	799	819	
98.7	90.6	93.6	84.1	93.3	92.6	91.3	84.1	89.1	91.3	95
658	592	650	654	655	616	597	477	600	625	
94.4	84.9	93.3	93.8	94.0	88.2	85.7	68.4	86.1	89.7	92
6.589	6.065	6.477	6.181	6.356	6.045	6.218	5.258	6.012	6.244	
97.6	89.8	95.9	91.5	94.1	89.5	92.1	77.9	89.0	92.5	93
4.758	4.649	4.714	4.580	4.421	4.503	4.491	3.701	4.339	4.527	
96.6	94.4	95.7	93.0	89.8	91.5	91.2	75.2	88.1	91.9	92
2.542	2.437	2.531	2.461	2.475	2.341	2.522	2.033	2.366	2.449	
97.3	93.3	96.9	94.2	94.7	89.6	96.5	77.8	90.6	93.7	93
30.55	27.94	29.87	28.82	29.20	29.07	29.16	25.47	28.34	29.11	
95.3	87.2	93.2	89.9	91.1	90.7	91.0	79.5	88.4	90.8	95
163	150	152	146	153	151	148	124	144	148	
100.0	97.5	93.3	89.6	93.9	92.6	90.8	76.1	88.3	90.8	95
97.1	91.1	94.5	90.9	93.0	90.7	91.2	77.0	88.5	91.6	94

CHART 4.—*Index numbers showing percentage variations of hourly output from limit of possible efficiency.*

TEN-HOUR PLANT—DEXTEROUS HANDWORK TYPE.

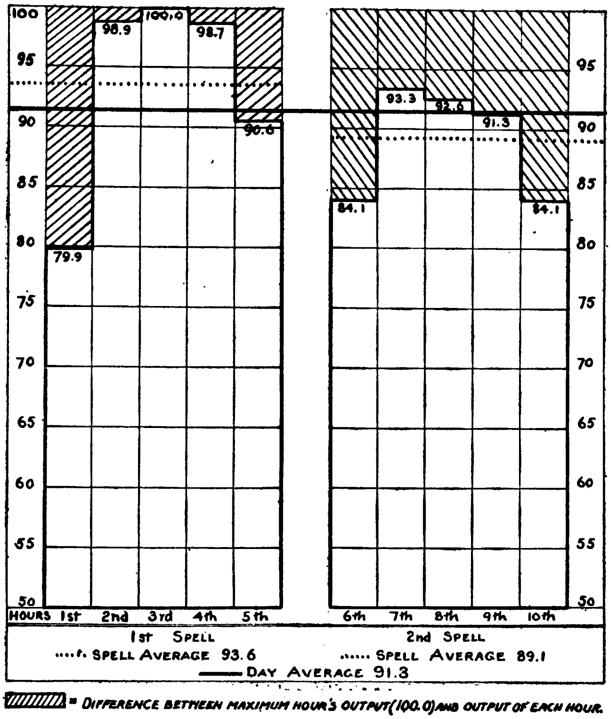


(a) Fuse Assembly.

An operation at the 10-hour plant comparable to the commutator loom process at the other factory is that of assembling and finishing the fuse (chart 5). In a large light workroom some 300 girls sit before three rows of tables running the full length of the room. They work together in batteries of 80 girls each. Before them the continuously moving conveyor carries past the respective parts of the fuse, top cap, rings, body, and bottom closing screws. These parts as they pass must be picked up and oiled, cleaned, brushed, gauged, screwed together, wrapped, and finally packed in tin containers for shipment. A few of the girls use drills or hand presses; for most of them it is hand work, exacting, dexterous, and rapid.

CHART 5.—*Index numbers showing percentage variations of hourly output from maximum hour's output.*

TEN-HOUR PLANT—FUSE ASSEMBLY.



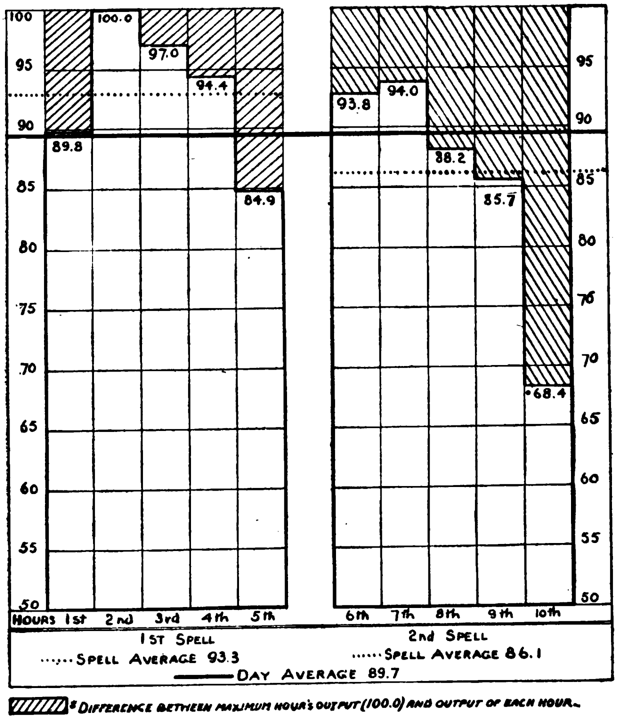
Just as in the corresponding example of dexterous handwork at the 8-hour plant, working capacity in this operation increases with the morning's practice. The rise in efficiency continues till the third hour in the morning and is followed by a scarcely appreciable decline which becomes abrupt in the fifth hour. In the afternoon practice has again to be attained; the rise is slighter and the fall heavier than in the morning. The maintenance of a high level of output during the middle part of each spell may be accounted for in part by the natural pacemaking of girls working in batteries; as all receive and deposit work on the same conveyor, no one girl can let it accumulate and block the rate of common progress. The output for the last hour in the day shows a drop of 16 per cent below the maximum hour.

(b) Painting Screw Holes with Lacquer.

Another example of a type of work requiring dexterity and attention is the process of painting screw-holes with lacquer (chart 6). Here the girl's task is to paint with lacquer the six screw holes in the bevel of the brass bottom closing screw of the fuse. She places the screw on the revolving stand before her, and, dipping her cotton-tipped stylus in the dish of lacquer at her right, applies it to each hole in rapid succession as she turns the screw. Since each hole must be completely lacquered, the worker must be exact and alert; the demands upon the eye and the attention are considerable.

CHART 6.—*Index numbers showing percentage variations of hourly output from maximum hour's output.*

TEN-HOUR PLANT—PAINTING SCREW HOLES WITH LACQUER.



The output curve for this operation is a modification of the type shown by fuse assembly; the greater strain and concentration required by the work is reflected in the earlier decline of output.

Here, however, the full effect of practice is reached more quickly, by the second hour, and from this maximum the output falls continuously and in the last hour sharply, till the end of the spell. In the afternoon the recovery at the beginning of the spell is excellent, but the rise from practice is very slight and the fall much heavier than in the morning. The last hour yields but two-thirds of the maximum output.

The ratio of the second to the first spell is 92, as compared to 95 in fuse assembly just described, and the average for the day only 89.7 as compared to 91.3. That this greater maintenance of stability in the first operation is not due to its being battery work is shown by the fact that the average (91.7) of all the remaining processes of the dexterous type is slightly higher than the single battery operation.

(c) Other Operations.

In the three operations of charging buttons, the peculiar spurt[1] in the late hours of the afternoon spell may have been due to the unusual eagerness observed on the part of these special groups of workers to increase their piecework wages.

MUSCULAR HANDWORK.

1. THE EIGHT-HOUR PLANT.

Studies of muscular handwork at the 8-hour plant were made in five operations. The results are presented in Table 3 and chart 7.

In this work requiring the exertion of muscular strength instead of attention and skill, there is less increase of efficiency from practice than in dexterous handwork, and efficiency falls more markedly throughout the day than in any other type. Maximum output for the day is reached earlier—that is, in the second, instead of the third hour of the morning spell—and fatigue develops sooner, the third hour beginning the decline, and the fall from maximum of the last hour before lunch averaging 8.5 as against 1.2 points in dexterous handwork. The average output for the afternoon is 4.6 points lower than the average for the morning spell—a fall exactly twice as great as in the dexterous type.

Another interesting difference between the two types, which is referred to above, is shown in the different levels of working power directly after the noontime break. As we have seen, in operations requiring dexterity and attention efficiency is low at the 8-hour plant in the hour after lunch and is only partly regained by a second slight increase from practice in the afternoon spell. But in muscular handwork, efficiency is comparatively high in the first hour after lunch, since the fatigue of the morning is counterbalanced by the noon break and work of this type shows no second gain from practice.

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[1] This should not be confused with the characteristic spurt in the late afternoon of stereotyped operations. See p. 85.

The fall of output in the afternoon spell continues steadily hour by hour. The production of the last hour is 15.2 points below the maximum hour.

In this type the variations within the group are noticeable. The heavier operations, such as ramming molds, excavate, and straighten bell, show a far greater fall in output than the lighter processes—radiator solder, and motor assembly. In both these last-named processes production runs an almost even course throughout the day, without the progressive fall which is characteristic of the heavier operations and of the type as a whole. Straighten bell holds a middle position in the group.

In this group, three of the five operations on which the composite curve is based, namely, the heavier operations already noted, reach their maxima in the second hour of the morning. At this hour accordingly the group curve reaches a maximum almost as high (99.6) as the limit of possible efficiency represented by 100. The dark area representing the difference (0.4 per cent) is therefore very narrow. The other operations reach their maxima in the following hour, the third, which is consequently the next highest point of the composite curve.

TABLE 3.—*Eight-hour plant,*

Operation.	Number of observations.	Starting time of shift.	Period of study.	(*a*) Number of units; (*b*) Index numbers.[1]	Average output observed each working hour.	
					First.	Second.
Radiator solder	236	7 a. m.	Sept. 15-Oct. 6	(*a*)	24.2	25.4
				(*b*)	**98.4**	**98.1**
Motor assembly	20	6.45 a. m.	Sept. 15-29	(*a*)	87.9	96.6
				(*b*)	**90.7**	**99.7**
Ramming molds	12	do.	Nov. 5-17	(*a*)	17.2	18.1
				(*b*)	**95.0**	**100.0**
Straighten bell	8	3.15 p. m.	Nov. 30-Dec. 10	(*a*)	144	157
				(*b*)	**91.7**	**100.0**
Excavate	6	6.30 a. m.	Dec. 17-22	(*a*)	373	383
				(*b*)	**97.4**	**100.0**
Average index numbers					**98.6**	**99.6**

[1] Index number=percentage variation from maximum; maximum=100.

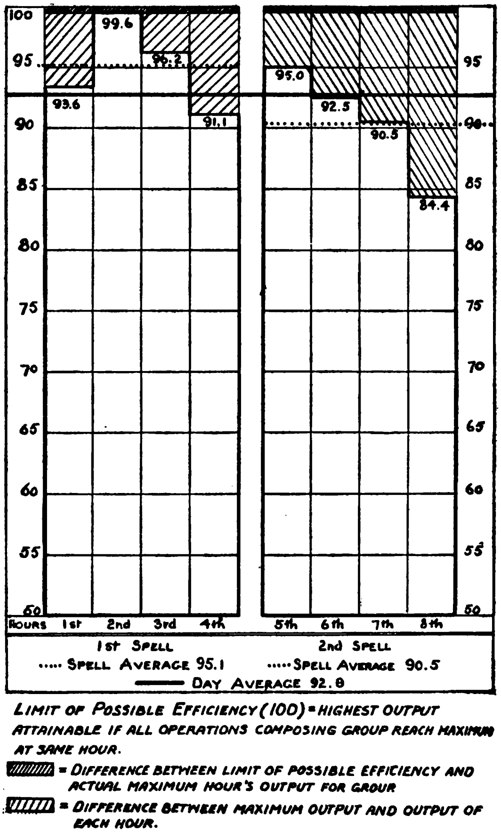
muscular handwork.

Average output observed each working hour.									Ratio of spells—second spell to first spell (in per cent).
Third.	Fourth.	Average for spell.	Fifth.	Sixth.	Seventh.	Eighth.	Average. for spell.	Average. for day.	
25.9	[2]25.8	25.3	24.9	25.9	25.4	25.5	25.4	25.4	
100.0	**99.6**	**97.7**	**96.1**	**100.0**	**98.1**	**98.5**	**98.1**	**98.1**	**100**
96.9	94.1	93.9	94.6	96.0	93.3	90.2	93.5	93.7	
100.0	**97.1**	**96.9**	**97.6**	**99.1**	**96.8**	**93.1**	**96.5**	**96.7**	**100**
17.7	16.8	17.4	16.5	16.0	15.4	14.3	15.5	16.5	
97.8	**92.8**	**96.1**	**91.2**	**88.4**	**83.1**	**79.0**	**85.6**	**91.2**	**89**
151	151	151	149	144	154	136	146	148	
96.2	**96.2**	**96.2**	**94.9**	**91.7**	**98.1**	**86.6**	**93.0**	**94.8**	**97**
334	267	339	364	319	287	248	304	322	
87.2	**69.7**	**88.5**	**95.0**	**83.3**	**74.9**	**64.8**	**79.4**	**84.1**	**90**
96.2	**91.1**	**95.1**	**95.0**	**92.5**	**90.5**	**84.4**	**90.5**	**92.9**	**95.0**

[2] Period of 1¼ hours. Actual output divided by ¼.

CHART 7.—*Index numbers showing percentage variations of hourly output from limit of possible efficiency.*

EIGHT-HOUR PLANT—MUSCULAR HANDWORK TYPE.



Ramming Molds.

The operation of ramming molds (chart 8) is in essence the packing or ramming of damp sand about a pattern so that when the pattern is removed the mold or cavity remains in the sand. Into this the molten metal is later poured. The pattern for the lower part of the cylinder mold, the "drag," stands in a large metal box or "flask" before the workers. One of them pulls the lid of the overhead sand chute or hopper releasing a shower of wet sand which partly fills the box, and is vigorously pounded down over the pattern by two men with heavy iron rammers; this steady pounding is kept up until the mold is full. The flask is then inverted by a mechanical device and the pattern is removed, the mold remaining clear and firm in the black sand. The heavy drag is lifted across by two men and set on the big chain conveyor; the "cope" or upper part of the mold, similarly made, is placed on top of it; and the completed mold travels down the room to the furnace and the casting.

As the men warm up to their work a rise in output is evident from the first to the second hour; from that point the decline is steady throughout the day, the last hour showing a fall, extraordinary for the eight-hour plant, of 21 points below the maximum. The ratio 89, showing the relative output of the two spells, indicates the deep fall in working capacity.

This is the heaviest work in the foundry; the heaviest, indeed, with one exception (excavating), at the 8-hour plant. Not only the work itself but all the attendant circumstances tend to favor the incidence of fatigue. Extremes of temperatures, alteration of dimness and glare, constant steam and fumes, the congestion of the workshop, greater than at any other point in the plant, and dangerous here as well as inconvenient, all add their quota to the essential muscular strain under which the men labor. According to the muscle strength test of Dr. E. G. Martin, this operation would seem to be too fatiguing for any but the strongest men. Many experiments made by this test proved the existence of what may be called a standard strength for each job,[1] to which the various individuals engaged in it tend closely to approximate. A man's strength, Martin suggests, will either develop to the standard strength required by his work, or may under persistent overstrain become permanently impaired. A large proportion of the men on this particular heavy job (23 out of 38) were shown by the strength test to be markedly under the standard strength for the job. Their strength moreover was disproportionately reduced by the day's work. While for the stronger men the impairment of strength due to a day's work averaged 4 per cent, that for the weaker men averaged as high as 12 per cent.

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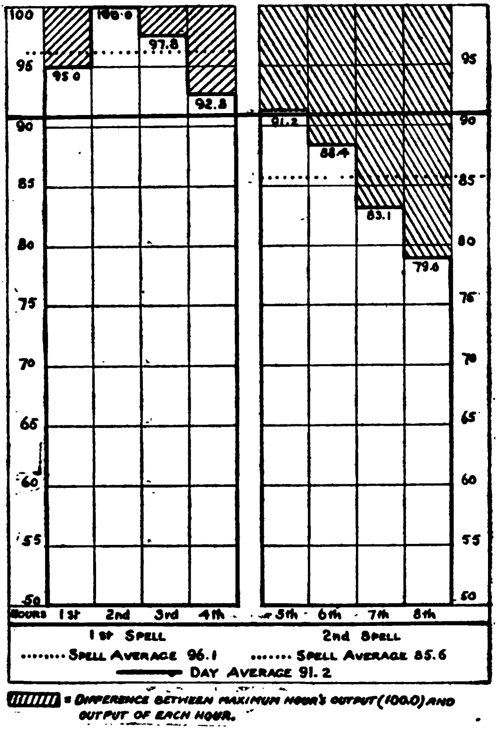
[1] The spring-balance strength test of Dr. E. G. Martin is a method of testing the total strength of the worker by tests of certain groups of selected muscles. The 10 muscles selected for the "standard short test" used are calculated to represent about one-fifth of the total strength of the subject, which can readily be computed from the results of the test. The job strength or standard strength for a given job is that to which the various total strength records for the workers on a given job most nearly approximate. Full results of this test will be reported in a later publication of the Public Health Service. Through the courtesy of Dr. Martin, certain preliminary figures are quoted in the present report.

CHART 8.—*Index numbers showing percentage variations of hourly output from maximum hour's output.*

EIGHT-HOUR PLANT—RAMMING MOLDS.



2. THE TEN-HOUR PLANT.

Studies of muscular handwork at the 10-hour plant were made in four operations. The results are presented in Table 4 and chart 9.

As at the 8-hour plant, maximum output for the day in this type of work is reached in the second hour of the morning spell. Here, too, the composite curve shows working capacity to be comparatively high after the lunch interval. The break affords recuperation, but in these operations efficiency does not gain again from practice in the afternoon spell, as it does in dexterous handwork.

The curve of the 10-hour plant differs from that of the 8-hour plant, in exhibiting a far more striking decline throughout the day, with a greater recovery after the noon break. The increase after lunch averages 9. 6 points against 3. 9 points at the other factory. But the effect of the longer day is shown in this type of work also, by the greater loss of output in the last additional hour of each working spell. At the 10-hour plant the fall from maximum averages 11.1 points and 35.1 points in the final hours of the morning and afternoon spells, as compared with a corresponding loss of 8.5 points and 15.2 points, respectively, in the final hours of the morning and afternoon spells at the 8-hour plant.

Under muscular handwork proper, as exemplified in planish seat given first in the table, there are included here three operations on hand-driven or foot-driven machines, retap top cap, graduate train ring and footpress assembly, because the kind of effort required approximates more closely to muscular handwork than to any other type of work.

In a group like this in which the component processes are not strictly homogeneous, it is natural that the maxima of individual operations should be distributed among different hours. This distribution lowers the maximum for the group (95) and gives us a wide band of dark hatching between that maximum and the limit of efficiency which is attainable only if the highest output in all operations is concentrated at the same hour.

The average output for the afternoon spell is 9.2 points lower than that of the morning, as against 4.6 at the 8-hour plant. The lowered efficiency of the afternoon is further shown in this group by the ratios between the work of the two spells, which are all uniformly lower than in dexterous handwork.

TABLE 4.—*Ten-hour plant,*

Operation.	Number of observations.	Starting time of shift.	Period of study (days).	(a) Number of units; (b) Index numbers.[1]	Average output observed each working hour.		
					First.	Second.	Third.
Planish seat	41	7 a. m.	14	(a)	584	553	519
				(b)	**93.6**	**88.6**	**88.2**
Retap top cap	195	...do...	17	(a)	520	478	490
				(b)	**100.0**	**91.9**	**94.2**
Footpress assembly	45	...do...	15	(a)	830	862	814
				(b)	**96.0**	**99.7**	**94.1**
Graduate train ring	47	...do...	16	(a)	703	950	954
				(b)	**73.7**	**99.6**	**100.0**
Average index numbers					**90.8**	**95.0**	**92.9**

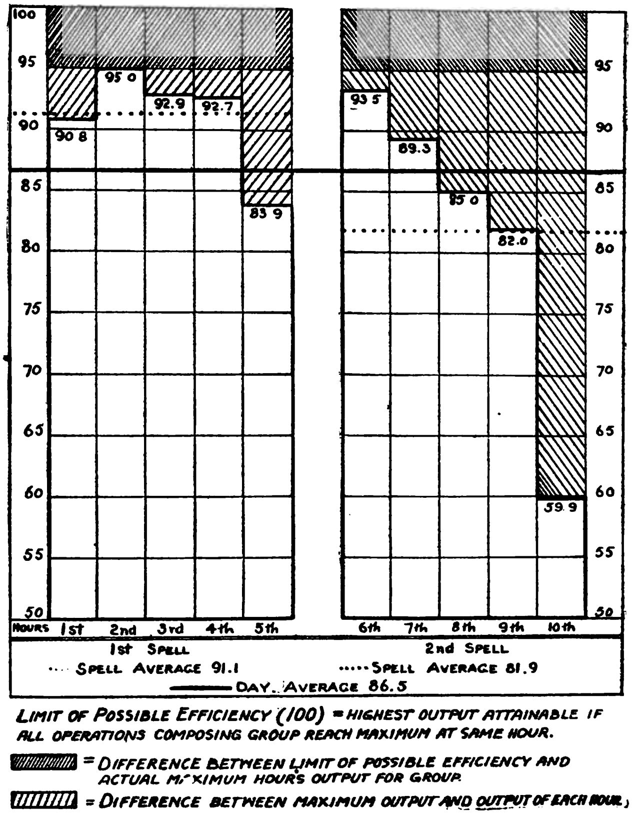
[1] Index number=percentage variation from maximum; maximum=100.

muscular handwork.

Average output observed each working hour.										Ratio of spells—Second spell to first spell (in per cent).
Fourth.	Fifth.	Average for spell.	Sixth.	Seventh.	Eighth.	Ninth.	Tenth.	Average for spell.	Average for day.	
540	428	525	624	534	457	462	339	483	504	
86.5	**68.6**	**84.1**	**100.0**	**85.6**	**78.2**	**74.0**	**54.3**	**77.4**	**80.8**	92
474	451	483	475	445	430	400	269	404	443	
91.2	**86.7**	**92.9**	**91.4**	**85.6**	**82.7**	**76.9**	**51.7**	**77.7**	**85.2**	84
832	865	841	840	800	798	782	741	792	816	
96.2	**100.0**	**97.2**	**97.1**	**92.5**	**92.3**	**90.4**	**85.7**	**91.6**	**94.3**	94
923	764	859	815	891	875	827	458	773	816	
96.8	**80.1**	**90.0**	**85.4**	**93.4**	**91.7**	**86.7**	**48.0**	**81.0**	**85.5**	90
92.7	**83.9**	**91.1**	**93.5**	**89.3**	**85.0**	**82.0**	**59.9**	**81.9**	**86.5**	90

CHART 9.—*Index numbers showing percentage variations of hourly output from limit of possible efficiency.*

TEN-HOUR PLANT—MUSCULAR HANDWORK TYPE.

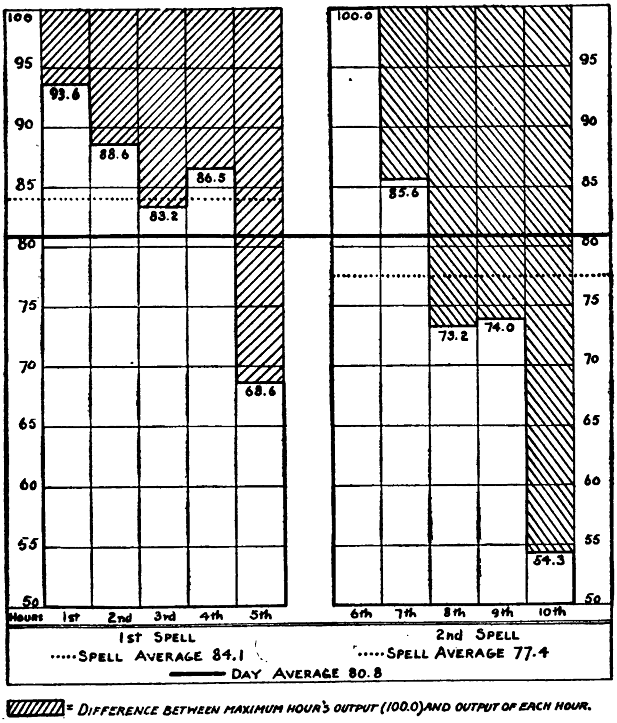


(a) Planish Seat.

The most characteristic instance of heavy handwork at the 10-hour plant is the operation called planish seat (chart 10) which files and smooths the bottom of the bottom closing screw of the fuse. The worker stands before a corrugated steel table or filing surface elbow high before him. From the rafter above, the polishing pole hangs from two springs, forming the capital letter Y. The lower end just reaches the corrugated table. The worker lays the screw on this rough surface with his left hand, seizes the pole with his right, and fits it into the middle of the screw. With the whole purchase of the pole he rubs the screw vigorously backward and forward several times, and with a final jerk snaps it sharply off into the chute beside him. Then, with hardly an appreciable pause, unless to brush off the filings, he has begun on the next screw. It is monotonous and fatiguing work, "the worst job in the room," as a worker at another task called it.

Chart 10.—*Index numbers showing percentage variations of hourly output from maximum hour's output.*

TEN-HOUR PLANT—PLANISH SEAT.



In its continued strain on certain groups of muscles, it disposes especially to the rapid onset of fatigue.

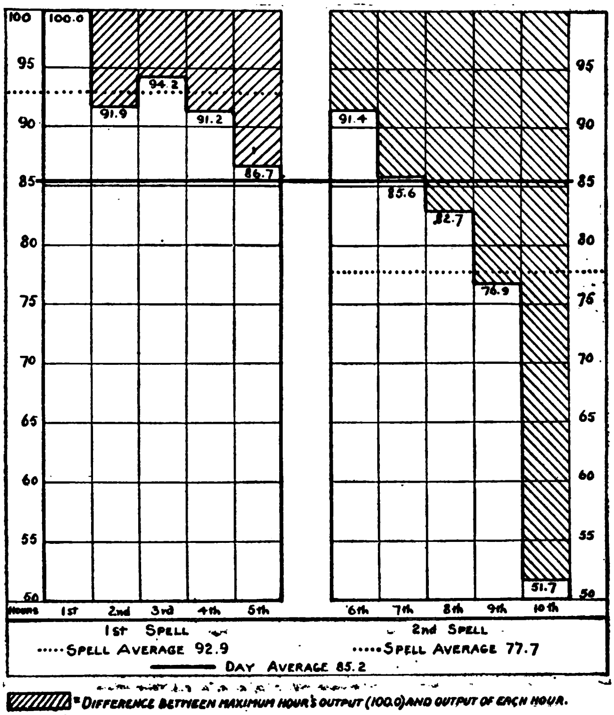
Here the output curve, high at the beginning of the shift, plunges almost steadily downward except for the notable recuperation after the noon interval. The operator begins the afternoon spell with the maximum output for the day, though the rate declines more swiftly and the curve falls more heavily than in the morning. In the fourth hour both morning and afternoon a slight recovery takes place which checks the decline, suggesting the "second wind" that occurs in strenuous exercise. The last hour's output shows a fall of 45.7 per cent from the maximum.

(b) Retap Top Cap, Etc.

A variation on the preceding type of production is shown by certain other kinds of monotonous muscular work involving the use of hand- or foot-driven machines. Such a process, for instance, is that called retap top cap (chart 11). The operation consists in cleaning out a small hole within the top cap of the fuse. The small hand-driven machine used in the process is not unlike a sewing machine with hand attachment. The worker sits before it revolving the wheel with her right hand. Through the hands of four or five women there pass daily the 20,000 odd fuse tops of the daily output. Each woman usually handles over 4,000. She feeds the caps one after

CHART 11.—*Index numbers showing percentage variations of hourly output from maximum hour's output.*

TEN-HOUR PLANT—RETAP TOP CAP.



another into the mounting; for each she makes five turns of the tap handle or wheel, then reverses five, detaches the cap and drops it into the chute—40,000 revolutions a day. The work is characterized by a high degree of automatism. In a monotonous operation of this kind, working capacity is highest in the first hour of work, and, as in planish seat, declines throughout the day, but with a much slighter recovery after the noon break.

Graduate train ring shows a deeper fall than any other operation in the group at the end of the day, but rises with practice both morning and afternoon. This is difficult to account for, since the operation is of the same general kind as retap top cap, but more strenuous. Men operate the machines, and apparently obtain some increase of efficiency from practice before working capacity declines.

The remaining operation in the group, footpress assembly, is less monotonous and makes demands less exclusively on muscular strength. It shows, therefore, some points of similarity with the curves of dexterous handwork. This operation has the steady decline of the muscular type in the afternoon, but fluctuates in the morning, rising to maximum in the fifth hour.

LATHE MACHINE WORK.

1. THE EIGHT-HOUR PLANT.

Studies of lathe machine work at the 8-hour plant were made in six operations. The results are presented in Table 5 and chart 12.

In lathe machine work, the curve of output shows marked differences from that of either muscular or dexterous handwork. Its most conspicuous features at the 8-hour plant are the exceptionally low level of the first hour of work, the slow gain in efficiency, the spurt after the lunch hour, and the maintenance of output in the last hour of the afternoon spell.

It should be noted that operations on lathe machines require muscular exertion, but in contrast to the narrow concentration required in the processes grouped under muscular handwork, the muscular activity in lathe work is both varied and rhythmic. It demands also a high degree of skill and attention.

Owing to the greater complexity and need of coordination in the work, efficiency, as might be expected, is lower at the beginning of the day than in either purely dexterous or muscular processes. Working capacity develops more slowly, and the output of the second hour—which is the maximum hour in muscular handwork and only 2 per cent below maximum in dexterous work—in lathe work is still 4.3 points below the maximum. A high level of output is reached in the third hour, followed by a fall in the fourth, less great than the fall in the final morning hour of muscular handwork but greater than in dexterous operations.

After the lunch interval, a characteristic spurt in the first hour again brings up output, this time to its maximum for the day. There is a drop after the spurt and thereafter a fairly sustained level for the last three hours, the production of the final hour declining only 6.4 points below maximum as contrasted with a fall of 15.2 and 9.3 points, respectively, in muscular and dexterous handwork.

Most striking of all in this curve is the absence of the typical fall of production at the end of the day. The output of the eighth hour is only slightly lower than that of the seventh hour, as compared with a fall of 6.1 points and 6.7 points, respectively, between the seventh hour and eighth hour in the two other types. Explanations of this peculiar maintenance of output will be discussed on page 63.

The shaded area in this chart is wider than in the other composite curves at the 8-hour plant, because the maxima (100) of only three of the seven operations of this type fall in the fifth hour. The curve for this type as a whole, therefore, falls 2.6 points below 100 at that hour. But the output for the day is not thereby lowered, because the dispersion of the maxima in other hours within the group raises their output, so that the loss is balanced.

TABLE 5.—*Eight-hour plant,*

Operation.	Number of observations.	Starting time of shift.	Period of study.	(a) Number of units; (b) Index numbers.[1]	Average output observed each working hour.	
					First.	Second.
First gear cutting	438	6.45 a. m.	Sept. 14–Oct. 6	(a)	39.1	47.2
				(b)	**82.7**	**99.8**
First gear cutting	400	3.15 p. m.	Sept. 14–Oct. 6	(a)	39.7	45.4
				(b)	**82.5**	**94.4**
Second gear cutting	59	6.45 a. m.	Sept. 14–28	(a)	109	122
				(b)	**73.7**	**82.4**
Axle grinding	577	6.15 p. m.	Sept. 19–Nov. 10	(a)	46.4	48.3
				(b)	**87.6**	**91.1**
Crank shaft grinding	439	3.30 p. m.	Sept. 15–Nov. 5	(a)	22.7	23.2
				(b)	**94.6**	**96.7**
Rear axle housing	469	3.15 p. m.	Sept. 13–29	(a)	18.8	20.1
				(b)	**87.9**	**93.9**
Average index numbers					**84.8**	**93.1**

[1] Index number = percentage variation from maximum; maximum = 100.

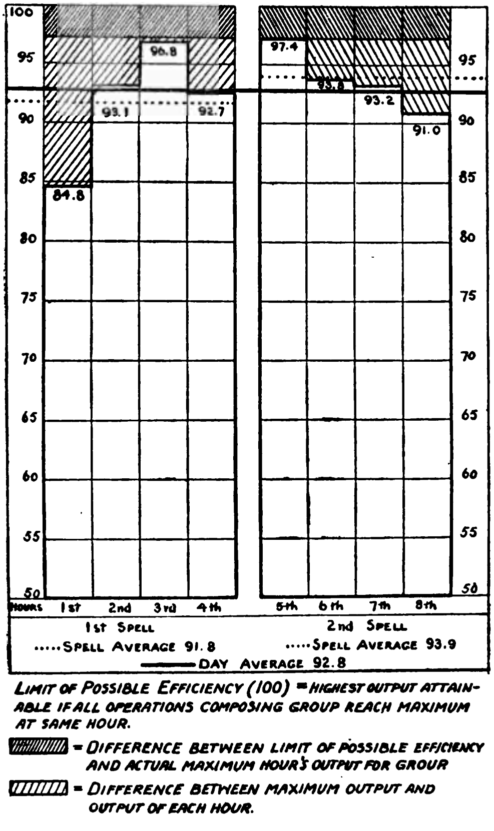
lathe machine work.

Average output observed each working hour.									Ratio of spells—second spell to first spell (in per cent).
Third.	Fourth.	Average for spell.	Fifth.	Sixth.	Seventh.	Eighth.	Average for spell.	Average for day.	
46.7	[2] 46.3	44.8	[3] 46.8	45.8	47.3	47.0	46.7	45.8	
98.7	**97.9**	**94.8**	**98.9**	**96.8**	**100.0**	**99.4**	**98.8**	**96.8**	**104**
[4] 46.3	[5] 42.2	43.4	48.1	47.0	45.7	45.8	46.6	45.0	
96.8	**87.7**	**90.2**	**100.0**	**97.7**	**95.0**	**95.2**	**97.0**	**93.6**	**107**
148	[2] 123	125	[3] 127	117	119	127	123	124	
100.0	**88.1**	**84.8**	**85.8**	**79.1**	**80.4**	**85.8**	**82.8**	**88.8**	**98**
49.5	49.7	48.5	53.0	49.3	48.6	42.0	48.2	48.4	
93.4	**93.8**	**91.5**	**100.0**	**93.0**	**91.7**	**79.8**	**91.0**	**91.3**	**99**
23.5	23.3	23.2	23.9	23.8	24.0	23.0	23.7	23.4	
97.9	**97.1**	**96.6**	**99.6**	**99.2**	**100.0**	**95.8**	**98.7**	**97.5**	**102**
20.2	20.6	19.9	21.4	20.7	19.7	19.4	20.3	20.1	
94.4	**96.3**	**93.1**	**100.0**	**96.7**	**92.1**	**90.7**	**94.9**	**93.9**	**102**
96.8	**92.7**	**91.8**	**97.4**	**93.8**	**93.2**	**91.0**	**93.9**	**92.8**	**102**

[2] Period of 1¼ hours; actual output divided by 5/4 to reduce to rate for 1 hour.
[3] Period of ¾ of an hour; actual output multiplied by 4/3 to reduce to rate for 1 hour.
[4] Period of 1½ hours; actual output divided by 3/2 to reduce to rate for 1 hour.
[5] Period of ½ hour; actual output multiplied by 2.

CHART 12.—*Index numbers showing percentage variations of hourly output from limit of possible efficiency.*

EIGHT-HOUR PLANT—LATHE MACHINE WORK TYPE.



LIMIT OF POSSIBLE EFFICIENCY (100) = HIGHEST OUTPUT ATTAINABLE IF ALL OPERATIONS COMPOSING GROUP REACH MAXIMUM AT SAME HOUR.

▨ = *DIFFERENCE BETWEEN LIMIT OF POSSIBLE EFFICIENCY AND ACTUAL MAXIMUM HOUR'S OUTPUT FOR GROUP*

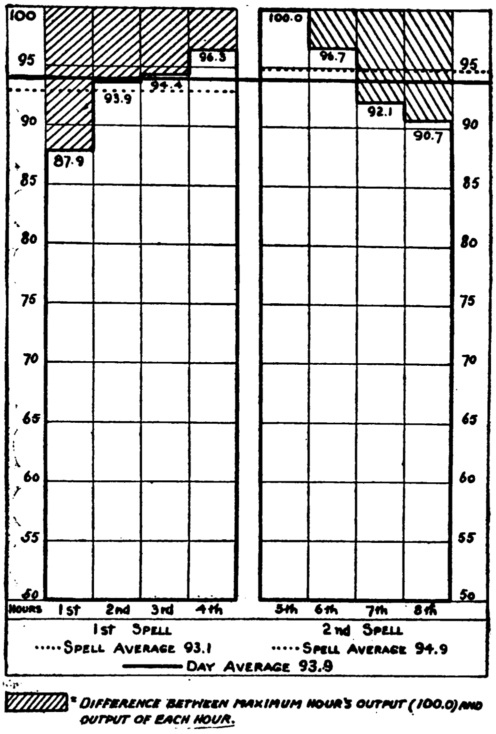
▨ = *DIFFERENCE BETWEEN MAXIMUM OUTPUT AND OUTPUT OF EACH HOUR.*

Rear Axle Housing.

In the heaviest of the lathe operations at the 8-hour plant, the process known as rear axle housing (chart 13) the output is remarkably stable. By this operation both halves of the rear axle housing or sheath are bored, faced, recessed and finished to fit upon each other, and to receive the axle and the differential gears. The machine is a huge lathe with two "saddles" or movable bases from which the tools are operated. That at the left holds a borer only, that at the right the turret with four other tools, the borer, reamer, roughing edge, and finisher. The rear axle housing, like a shallow bell with a long handle, still rough metal, is clamped into the machine with a crowbar so that the handle or tube end is at the left, facing the borer, and the bell end facing the turret with the remaining tools. The operator throws on the power by the overhead clutch, moves the two saddles toward the axle housing, and applies the boring tools to each end of the tube. Then by lever and wheel he revolves the lathe turret and applies the other tools to the bell in turn, reaming the hollow tube, roughing or recessing the outer rim of the bell, and

CHART 13.—*Index numbers showing percentage variations of hourly output from maximum hour's output.*

EIGHT-HOUR PLANT—REAR AXLE HOUSING.



finishing or smoothing the burrs from the polished steel rim. When completed, the bell is the "male" to the "female" end of the differential covering, made by a similar process and recessed reversely, upon which it exactly fits to form the complete rear axle housing.

This is heavy responsible work, demanding not only powerful muscles, but careful attention and exact judgment. Of the tools used in the process only half are set, and as the process continues the operator bends over and watches his work intently. Certain points on the rim, designed to hold the bolts, must be gauged with great exactitude, a minute fractional error rendering the parts useless. Yet, in spite of the evident and undeniable demands upon attention, the pace of the operator varies only slightly throughout the day. With the exception of a single hour the curve of production is almost exactly parallel to the composite curve of the type.

2. THE TEN-HOUR PLANT.

Studies of lathe machine work at the 10-hour plant were made in two operations. The results are presented in Table 6 and chart 14.

At the 10-hour plant the workers on lathe machines begin work at a lower level of efficiency than at the 8-hour plant and take longer to improve by practice. Working capacity increases during the second and third hours of the morning spell, until maximum is reached in the fourth. The fifth hour again falls.

The greatest difference in the curves of lathe machine work at the two factories is seen in the hour after the lunch interval, when the output declines further at the 10-hour plant, instead of showing the extraordinary spurt which occurs at this hour at the other factory.

In the remaining hours of the afternoon, however, under the 10-hour as well as under the 8-hour day, this type of work exhibits the greater stability of production which differentiates it from both muscular and dexterous handwork. At the 10-hour plant the three middle hours of the afternoon show a progressive though slight improvement, and the final hour of the afternoon spell falls from maximum only 11.3 points, while, as we have seen, in the two other types of work it falls 35.1 and 21.5 points, respectively.

In this chart alone among the composite curves the maximum hour's performance, owing to the homogeneity of the group, reaches the limit of possible efficiency. This is due to the coincidence in the fourth hour of the peaks of production of its two component operations. There is, therefore, no area of dark hatching in this figure. It is clear that, as in the other types of work, such a coincidence of maxima raises the day's output no higher than their dispersion would, since the higher peak at one hour is balanced by a deeper decline elsewhere.

TABLE 6.—*Ten-hour plant,*

Operation.	Number of observations.	Starting time of shift.	Period of study (days).	(*a*) Number of units; (*b*) Index numbers.[1]	Average output observed each working hour.		
					First.	Second.	Third.
Spin top cap........................	89	7 a. m.....	17	(*a*)	153	190	208
				(*b*)	**69.5**	**86.4**	**94.5**
Face and score train ring........	45	....do......	17	(*a*)	245	383	361
				(*b*)	**60.8**	**95.0**	**89.6**
Average index numbers..	....	....	....	....	**65.1**	**90.7**	**92.0**

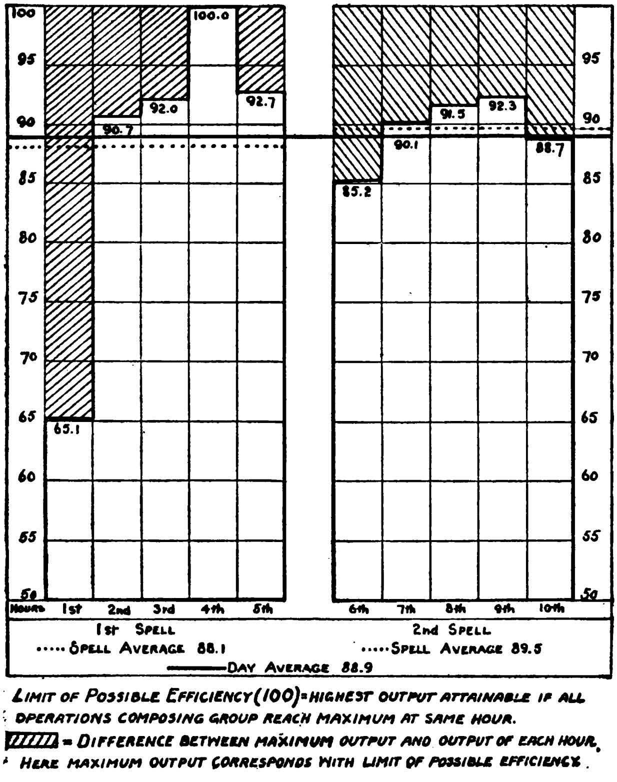
[1] Index number = percentage variation from maximum; maximum = 100.

lathe machine work.

Average output observed each working hour.										Ratio of spells—second spell to first spell (in per cent).
Fourth.	Fifth.	Average for spell.	Sixth.	Seventh.	Eighth.	Ninth.	Tenth.	Average for spell.	Average for day.	
220	214	197	205	203	211	206	205	206	202	
100	**97.8**	**89.6**	**93.2**	**92.8**	**95.9**	**93.6**	**93.2**	**93.6**	**91.8**	105
403	355	349	311	354	351	367	339	344	347	
100	**88.1**	**86.6**	**77.2**	**87.9**	**87.1**	**91.1**	**84.1**	**85.4**	**86.1**	**99**
100	**92.7**	**88.1**	**85.2**	**90.1**	**91.5**	**92.8**	**88.7**	**89.5**	**88.9**	**102**

CHART 14.—*Index numbers showing percentage variations of hourly output from limit of possible efficiency.*

TEN-HOUR PLANT—LATHE MACHINE WORK TYPE.

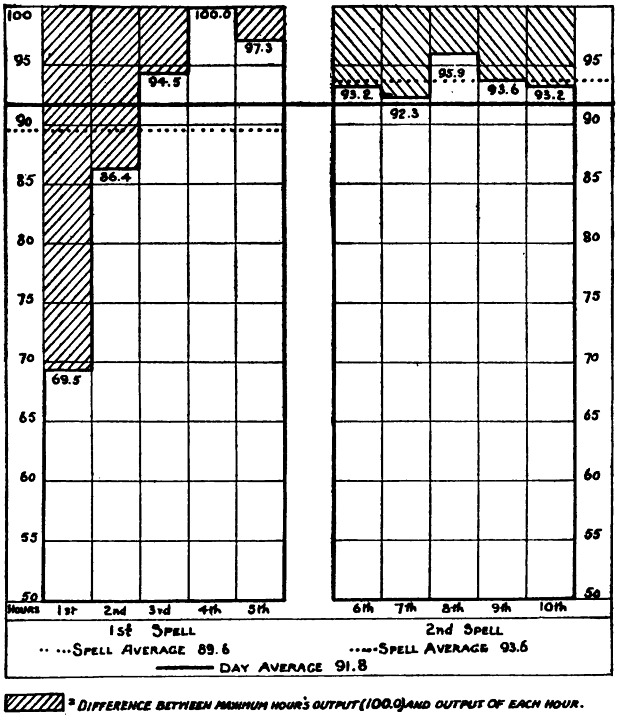


Spin Top Cap.

A good example of lathe work at the 10-hour plant is the operation known as spin top cap (chart 15) which forms, grooves, and finishes the top cap of the fuse. Standing before his lathe the operator takes the rough metal cap from the pile at his right and inserts it in the mounting. He turns on the power by the overhead lever, catches the side lever in both hands, lifts it, throws his body against it, and by that pressure applies the forming tool. Then vigorously throwing on and off other levers in succession, he applies the other tools in turn, indenting a recess half way down the cap, "spinning the top cap," disengaging the tools, and disconnecting the finished cap.

CHART 15.—*Index numbers showing percentage variations of hourly output from maximum hour's output.*

TEN-HOUR PLANT—SPIN TOP CAP.



There is spring, movement, variety about such work as this; it lends itself to balanced rhythm. The various groups of muscles called into action, the pulling, pushing, raising, and lowering, seem to relieve and balance each other. It is hard work, yet not so hard as many less taxing but monotonous operations. Far more tiring is the narrow concentrating of a single muscle group in a single process, such as planish seat or retap top cap. Thus, while the output of these latter operations for the last hour falls nearly one-half of the maximum hourly output, the last hour's output for spin top cap is only 6.8 per cent below maximum.

Thus at both the 10-hour and 8-hour plants the stability of output in lathe work is conspicuous. In view of the fact that these are heavy operations requiring both muscular effort and dexterity, a fall of output toward the end of each spell might reasonably be expected. Further explanation of the sustained performance of the operators is clearly needed.

In the operation of spin top cap, it is evident from our observations that the time lost by the workers in the course of the day contributes materially to the maintenance of production. Eighty-seven observations showed that an average of almost two and a quarter hours was lost per worker each day.[1] Of this time about three-quarters of an hour was lost in starting and stopping work. Almost one and a half hours were lost by involuntary stoppages during the rest of the day, for which the worker was in no way accountable. Clearly, the reduction of working time and the amount of rest afforded by these interruptions, even though irregular and often associated with irritation at the delay, must to some extent balance exertion and give time for partial muscular recovery in the actual progress of the work. After a longer spell of work even in this operation, as on the night shift where the spells are six hours long instead of five, output shows its usual drop in the final hour.

That this loss of time is not typical in lathe work, however, is shown by the fact that in the only other unstereotyped[2] lathe operation studied at the 10-hour plant, face and score train ring, the time lost is less than one-third as great as in spin top cap (38 minutes). At the 8-hour plant also the comparatively slight loss of time can not account for the even level of production.

A more inclusive explanation must therefore be sought. In the phenomenon of rhythm, present in lathe work to a far greater degree than in either muscular or dexterous handwork, recent investigations by Dr. P. S. Florence and Dr. A. H. Ryan, of the Public Health Service, suggest that the explanation of the peculiar stability of lathe operations is to be found. How rhythm contributes to such stability of output by masking the fall of working capacity and why the maintenance of capacity toward the end of the day is not to be ascribed to the absence of fatigue are questions discussed at some length in chapter 9, on Rhythm in Industry, pages 200–210.

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[1] Table 11, p. 79.

[2] For definition and discussion of stereotyping, see chapter 4.

MISCELLANEOUS MACHINE WORK.

1. THE EIGHT-HOUR PLANT.

Studies of miscellaneous machine work at the 8-hour plant were made in eight operations. The results are presented in Table 7 and chart 16.

In the processes grouped under miscellaneous machine work, output is even more steadily maintained than in lathe machine work. As in lathe work, efficiency is lower at the beginning of the day than in the two other types of work considered. There is, again, a slow rise from practice during the first two hours of the morning spell and maximum is reached by the third hour. For the remainder of the day output remains very high and varies but slightly. The seventh hour falls only 0.9 points below maximum and the final hour only 3.6 points. In one of the operations included in the group and studied on both day and evening shifts, brazing collars, the output of the last hour is actually the highest. In only one of the processes—drop forge—does the output of the afternoon fall below that of the morning. In all the others it is just equal to or higher than that of the morning.

This extraordinary maintenance of production is, in part, explained by the mechanical nature of most of the operations contained in this group. In brazing, especially, output is to a large extent mechanically maintained. The operator must await the completion of the furnace processes and it is true that the intervals of rest, amounting sometimes to three or four minutes at a time, may go far to balance exertion and postpone the onset of fatigue. Yet a large output at the close of the shift does not necessarily mean that working capacity is still at its height or that fatigue has not developed in the course of the work.

For the type of work as a whole, the output of the last hour is somewhat unduly influenced by the high final records in some of the brazing processes. As stated at the outset, the operations included in the several types of work are not strictly homogeneous. Allowance must be made for individual variations within the group. In miscellaneous machine work, as its name implies, there are noticeable differences between the separate processes. Yet, in spite of the wide dispersion of the maxima in the separate operations, the level of the individual curves is so steadily maintained that the highest peak of production for the group as a whole is only 1.6 below 100.

TABLE 7.—*Eight-hour plant.*

Operation.	Number of observations.	Starting time of shift.	Period of study.	(*a*) Number of units; (*b*) Index numbers.[1]	Average output observed each working hour.	
					First.	Second.
Crank-case grinding	69	7 a. m.	Sept. 19–Oct. 13	(*a*)	[2] 41.4	45.1
				(*b*)	**86.8**	**94.5**
Do	90	3.30 p. m.	do	(*a*)	38.3	42.1
				(*b*)	**86.7**	**95.3**
Brazing hangers	506	7 a. m.	Sept. 17–Dec. 22	(*a*)	[2] 29.2	31.7
				(*b*)	**92.1**	**100.0**
Do	493	3.30 p. m.	do	(*a*)	30.9	31.3
				(*b*)	**95.1**	**96.3**
Brazing collar	312	7 a. m.	Sept. 19–Dec. 22	(*a*)	[2] 47.1	53.3
				(*b*)	**82.6**	**93.5**
Do	280	3.30 p. m.	do	(*a*)	49.8	54.1
				(*b*)	**85.9**	**93.3**
Drop forge	17	7 a. m.	Dec. 26–Jan. 11	(*a*)	118	119
				(*b*)	**93.7**	**94.5**
Small punch presses	24	do	Jan. 15–Feb. 2	(*a*)	658	697
				(*b*)	**86.6**	**91.7**
Average index numbers					**88.7**	**94.9**

[1] Index number=percentage variation from maximum; maximum=100.
[2] Period of 1½ hours; actual output divided by 3/2 to reduce to rate for 1 hour.

miscellaneous machine work.

Average output observed each working hour.									Ratio of spells—second spell to first spell (in per cent.)
Third.	Fourth.	Average for spell.	Fifth.	Sixth.	Seventh.	Eighth.	Average for spell.	Average for day.	
47.7	46.1	45.1	[3] 44.0	[3] 44.0	47.1	46.9	45.5	45.3	
100.0	**96.6**	**94.5**	**92.2**	**92.2**	**98.7**	**98.3**	**95.3**	**95.0**	**101**
44.2	40.4	41.2	39.3	41.8	41.6	42.2	41.2	41.2	
100.0	**91.4**	**93.2**	**88.9**	**94.6**	**94.1**	**95.5**	**93.3**	**93.3**	**100**
31.3	31.2	30.8	[4] 31.9	31.1	31.4	30.1	31.1	31.0	
98.7	**98.4**	**97.3**	[5] **100.6**	**98.1**	**99.1**	**95.0**	**98.2**	**97.8**	**101**
31.7	31.4	31.3	32.5	31.6	30.9	29.9	31.2	31.3	
97.5	**96.6**	**96.4**	**100.0**	**97.2**	**95.1**	**92.0**	**96.1**	**96.3**	**100**
54.3	54.3	52.2	[4] 55.9	56.1	55.8	57.0	56.2	54.2	
95.2	**95.2**	**91.6**	**98.1**	**98.4**	**97.9**	**100.0**	**98.6**	**95.1**	**108**
56.1	57.4	54.3	55.1	57.0	55.5	58.0	56.4	55.4	
96.7	**99.0**	**93.7**	**95.0**	**98.3**	**95.7**	**100.0**	**97.3**	**95.5**	**104**
126	126	122	117	114	125	110	116	119	
100.0	**100.0**	**97.0**	**92.9**	**90.5**	**99.2**	**87.3**	**92.5**	**94.4**	**95**
751	735	710	723	738	760	683	726	718	
98.8	**96.7**	**93.5**	**95.1**	**97.1**	**100.0**	**89.9**	**95.5**	**94.5**	**102**
98.4	**96.7**	**94.7**	**95.4**	**95.8**	**97.5**	**94.8**	**95.9**	**95.3**	**101**

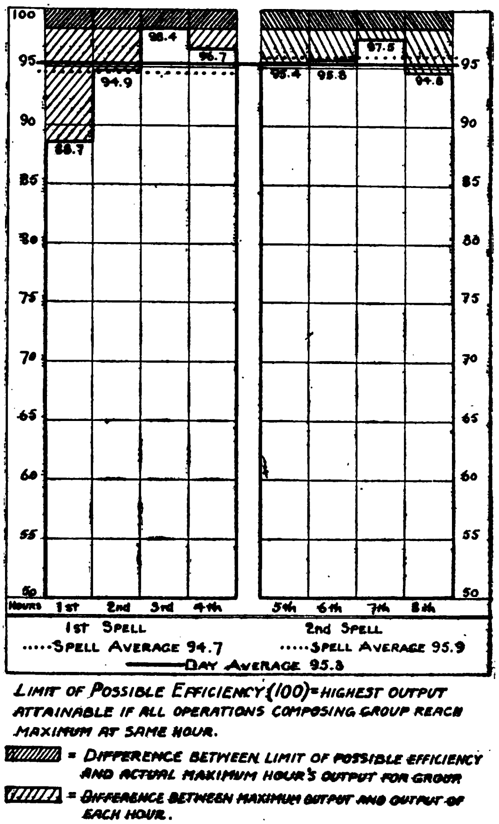
[3] Period of 1½ hours; actual output multiplied by 4/3 to distribute equally over 2 hours.

[4] Period of ½ hour; actual output multiplied by 2.

[5] See footnotes, pp. 14 and 28.

CHART 16.—*Index numbers showing percentage variations of hourly output from limit of possible efficiency.*

EIGHT-HOUR PLANT—MISCELLANEOUS MACHINE WORK TYPE.

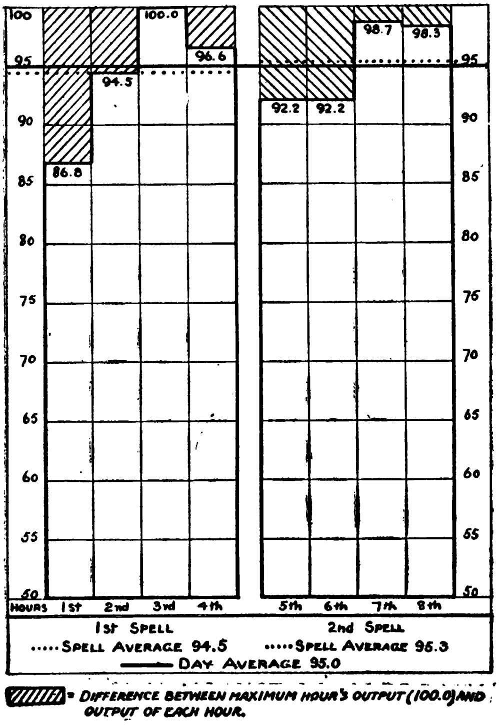


Crank Case Grinding.

The task of the worker in this process (chart 17) is to grind smooth the rough edges left by the brazing and welding processes on the "collar" and "flange" of the two halves of the metal crank cases, so that these halves may precisely fit upon each other. The crank case is about two and one-half feet long, an irregular oval container into which the crank shaft is fitted, made of sheet steel and weighing some 30 pounds. Two kinds of grinding machines are used, a single machine and a double. With the single type of machine, one worker grinds the two ends of the crank case in succession, bracing it against thigh and hip as he applies it to the grinding wheel. With machines of the double type, equipped with holders into which the crank cases are inserted, two operators divide the work, one of them grinding the right sides and one the left sides of the successive cases. Muscular effort and coordination are alike demanded by the operation. Where the operator must himself support the cases, the work is muscularly taxing, but with either type of machine the strain on attention during the actual grinding is unremitting. Only by careful examination can the worker regulate the contact time of crank case edge and grinding surface.

CHART 17.—*Index numbers showing percentage variations of hourly output from maximum hour's output.*

EIGHT-HOUR PLANT—CRANK CASE GRINDING (MORNING SHIFT).



The presence of this combined neuro muscular demand might be expected to result in a marked decline of working capacity in the second spell. But in the two shifts studied, the spell average for the second spell in the morning shift is slightly higher than that for the first spell; in the evening shift the two spell averages are the same. Especially noticeable in both shifts is the high relative level of the performance of the seventh and eighth hours. This is most markedly the case in the morning shift, on the figures of which for purposes of better comparison with the day-shift figures of the 10-hour plant, the curve in chart 17 has been plotted.

2. THE TEN-HOUR PLANT.

Studies of miscellaneous machine work at the 10-hour plant were made in three operations. The results are presented in Table 8 and chart 18.

At the 10-hour plant, as at the 8-hour plant, the operations grouped under miscellaneous machine work are more stable in output than in any other type of work.

The characteristic differences between the two plants are again illustrated. The rise from practice is slower and more prolonged at the 10-hour plant, maximum not being reached until the fourth hour; and the fall of the last hour both morning and afternoon is greater. But the fall of the final hour is almost negligible in this type of work compared with any of the others, being 8.4 points below maximum, as against 21.5 per cent, 35.1 per cent and 11.3 per cent, respectively, in dexterous handwork, muscular handwork, and lathe work.

As in two out of the three operations under this type the maxima coincide in the fourth hour, the maximum performance for the group falls very little (0.9) below the limit of efficiency.

TABLE 8.—*Ten-hour plant,*

Operation.	Number of observations.	Starting time of shift.	Period of study (days).	(a) Number of units; (b) Index numbers.[1]	Average output observed each working hour.		
					First.	Second.	Third.
Cover fabric on dial press	47	7 a. m.	15	(a)	1,998	2,226	2,284
				(b)	87.5	97.5	100
Form springs on dial press	54	...do.	15	(a)	1,400	1,398	1,684
				(b)	85.0	84.8	99.1
Buffing (coloring razor frames)	76	...do.	19	(a)	209	229	237
				(b)	86.0	94.2	97.5
Average index numbers					86.2	92.2	98.9

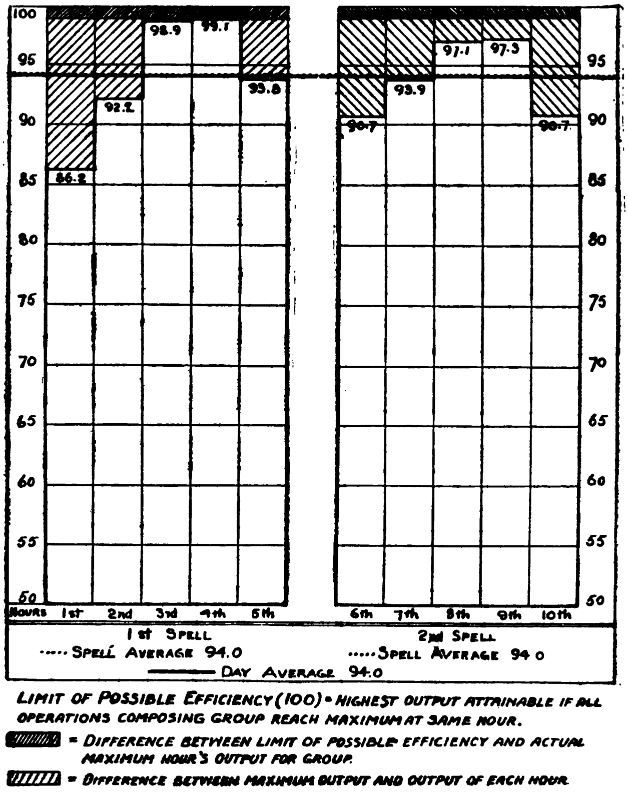
[1] Index number = percentage variation from maximum; maximum = 100.

miscellaneous machine work.

Average output observed each working hour.										Ratio of spells—second spell to first spell (in per cent).
Fourth.	Fifth.	Average for spell.	Sixth.	Seventh.	Eighth.	Ninth.	Tenth.	Average for spell.	Average for day.	
2,225	2,091	2,165	2,052	2,121	2,244	2,193	2,145	2,151	2,158	
97.4	91.6	94.8	89.8	92.8	98.3	96.0	93.9	94.2	94.5	99
1,648	1,513	1,519	1,452	1,471	1,538	1,605	1,504	1,514	1,516	
100	91.8	92.2	88.1	89.3	93.3	97.4	91.3	91.9	92.0	100
243	238	231	229	242	242	239	211	233	232	
100	98.0	95.1	94.2	99.6	99.6	98.4	86.8	95.9	95.5	101
99.1	93.8	94.0	90.7	93.9	97.1	97.3	90.7	94.0	94.0	100

CHART 18.—*Index numbers showing percentage variations of hourly output from limit of possible efficiency.*

TEN-HOUR PLANT—MISCELLANEOUS MACHINE WORK TYPE.

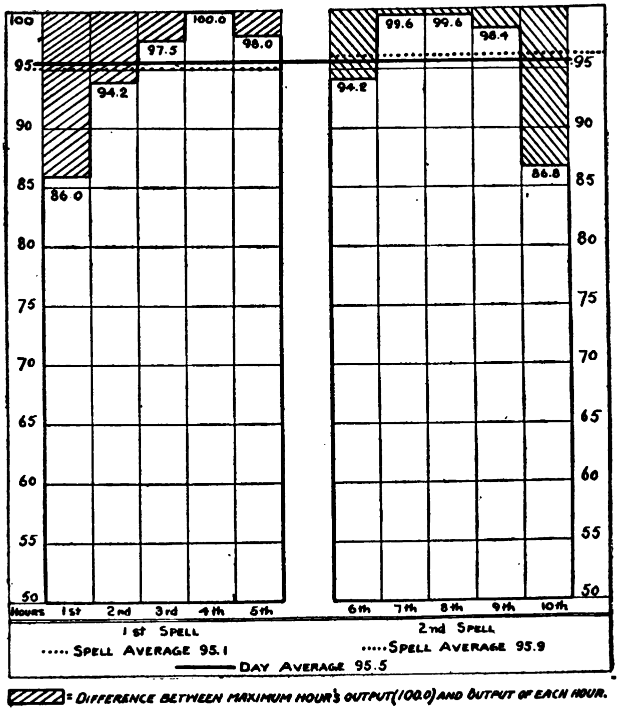


Buffing Razor Frames.

This operation (chart 19), while far lighter in the muscular strain involved, is somewhat analogous to the heavy operation of crank case grinding at the 8-hour plant. The operator, standing before the swiftly revolving felt buffing wheel, holds pressed against it the oblong case or holder containing eight razor frames. The frames must be passed eight times over the rouged wheel, turning their several sides to the revolving felt to "clean" or polish them. Some half-dozen more passes are required to color them inside and out in preparation for nickel plating. Thus each set of eight razor frames must be applied 14 or 15 times to the buffing wheel in the course of this operation, each application involving a considerable tension of muscle and exercise of dexterity. In addition to this central part of the process there are many exact and dexterous movements to be executed in the course of the work: slipping the frames into the holder, closing and opening them, according to the requirements of the buffing, and pushing them off the holder into the finished pile.

CHART 19.—*Index numbers showing percentage variations of hourly output from maximum hour's output.*

TEN-HOUR PLANT—BUFFING RAZOR FRAMES.



Except for the falls of the first and last hours, the high level of production in this operation is remarkable. The last morning hour drops only two points below the maximum in the fourth hour, and, excluding the first and last hours of the day, the day average would reach the extraordinarily high level of 97.7. The fall of the last hour, 11.6 points, is, on the other hand, a marked one.

COMPARATIVE MAINTENANCE OF OUTPUT AT THE TWO PLANTS.

At the beginning of this chapter (p. 27) we noted that at the 10-hour plant the output for the different hours of the day shows a much greater decline from the maximum hour than at the 8-hour plant. This is illustrated by chart 20 which presents the combined results of all of our observations. These curves are based on representative figures for output obtained as follows:

Though the exact numbers of men engaged in each of the four types of work at the 8-hour plant are not available, since no occupational census was taken, we may fairly assume from figures given in a recent careful study for a typical automobile factory that each type represents about one-fourth of the total work of the plant.[1]

Hence in order to obtain representative figures for the curve of output in the plant as a whole, we may now average the average index numbers of the four types of work. The figures for the 8-hour plant are as follows:

Hourly output of the eight-hour plant—Index numbers showing fall from maximum.

Hours.	First.	Second.	Third.	Fourth.
Morning spell	89.6	96.4	97.4	94.4
Afternoon spell	95.7	94.4	94.2	89.8

In tracing the variation of the individual curves within each type we have noted that their maxima rarely coincide. Even where several of the component curves were so closely parallel as to reach the maximum at the same hour, the distribution of the other maxima so lowered the peak of production of the group that its maximum fell more or less below the limit of possible efficiency.

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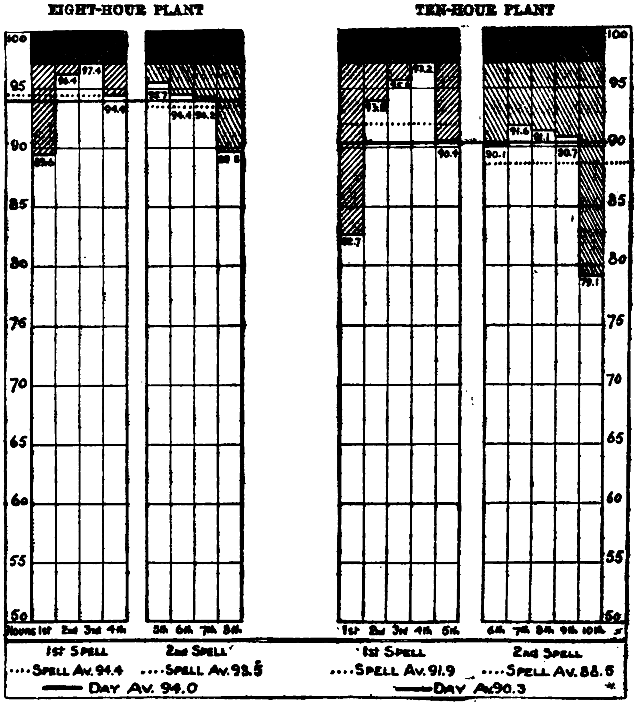
[1] In a report on the metal trades published by the Cleveland Educational Survey in 1916 (Cleveland Education Survey, R. R. Lutz. The Survey Committee of the Cleveland Foundation, 1916, p. 82), information of this nature has been given with regard to a typical automobile factory in Cleveland. Taking the operations as classified at the 8-hour plant, we find roughly 43 per cent of the employees engaged in machine work, of which 27 per cent belongs to the lathe type and over 16 per cent is miscellaneous. Of the remaining 57 per cent engaged in handwork, there are 27 per cent whose work corresponds to dexterous handwork, and 29 per cent whose work corresponds to muscular handwork. At the 8-hour plant, where mechanical devices have been carried unusually far in economizing hand labor, the miscellaneous machine type, which is low in the Cleveland factory, includes a larger proportion of workers, so that the four classes or types of work would be approximately equal. A rough departmental analysis made at the 8-hour plant confirms this conclusion.

If such is the result even where similar operations are grouped in a single type, it will be inevitable when the group curves are combined to form the output curve for the plant as a whole. These group curves, representing the output of wholly different types of work, are naturally dissimilar. The distribution of the four group maxima in different hours leaves the maximum hour's production for the plant as a whole 2.6 points in one case, and 2.8 points in the other below possible efficiency

CHART 20.—*Index numbers showing percentage variations of hourly output from limit of possible efficiency.*

TOTAL OF REPRESENTATIVE OPERATIONS.



Limit of possible efficiency (100)=highest output attainable if all operations reach maximum at same hour.

▩ = Difference between limit of possible efficiency and actual maximum hour's output.

▨ = Difference between maximum output and output of each hour.

The remarkably sustained approximation to maximum at the 8-hour plant becomes the more striking by comparison with the deep fall of output in the comparable operations and types of work at the 10-hour plant.

For a fair comparison of working capacity and production at the two plants it is obviously necessary to compare the output of processes and types as nearly alike as possible at each factory in order to exclude all differences except the point at issue, that is, the difference in the length of the workday. Obviously again, in a general metal-working establishment such as the 10-hour plant, there are many processes and operations not included in the representative output of the automobile factory.[1] We must, therefore, for our present purpose take figures representing not the total activity of the factory but the average of the four types of work studied at the eight-hour plant. The resultant figures are as follows:

Hourly output of the ten-hour plant—Index numbers showing fall from maximum.

Hours.	First.	Second.	Third.	Fourth.	Fifth.
Morning spell	82.7	93.8	95.6	97.2	90.4
Afternoon spell	90.1	91.6	91.1	90.7	79.1

Comparing now the figures for the two factories, we find the sustained approximation to maximum of the 8-hour plant contrasting sharply with the much deeper fall of output at the 10-hour plant. At the 8-hour plant the range of deviation in six out of eight of the hourly output figures, or three-quarters of the hours, is only 3.2 points and the remaining two hours drop only 4.6 points further. At the 10-hour plant, on the other hand, only two out of the 10 hours fall within the same range of deviation; the remaining eight hours are distributed downward over four times as great a range, or 14.7 points. This contrast is strikingly evident in the accompanying tabular statement:

8-hour plant.	10-hour plant.
97.4	
96.4	
95.7	
94.4	
94.4	97.2
94.2	95.6
89.8	93.8
89.6	91.6
	91.1
	90.7
	90.4
	90.1
	82.7
	79.1

If we further compare corresponding hours of work at the two plants, we find that the notable difference lies in the far greater loss during the first and last hours of each spell at the 10-hour plant, and the much lower level of the entire second spell.

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[1] The method of obtaining representative output figures for the 10-hour plant based on the distribution of workers in the factory is given in detail on pp. 136 to 139. Care has been taken to eliminate the records of all workers who were employed overtime in addition to the 10-hour day.

CHAPTER 3.

LOST TIME.

At the 8-hour plant, work with almost full power begins and ends approximately on schedule, and lost time throughout the day is reduced to a minimum.

At the 10-hour plant work ceases regularly before the end of the spell, and lost time throughout the day is frequent.

A study of lost time at the 8- and the 10-hour plants shows a sharp contrast between the two, similar to that presented in our last chapter in the matter of working up to capacity. For the sake of convenience we shall consider the subject here under the heads of time lost in starting and stopping work; and time lost throughout the day. Especially in regard to time lost in starting and stopping work the difference between the two factories is conspicuous to any observer.

TIME LOST IN STARTING AND STOPPING WORK.

At the 8-hour plant, the workers in the various departments start and stop work practically on schedule. In one department, for instance, transmission gear cutting, observation showed that only two minutes was lost at the end of the morning shift; work also started punctually, 7 minutes being required to get under way in the morning shift, 3 minutes on the afternoon shift.

At the 10-hour plant, on the other hand, fully 15 minutes before the noon hour and fully 30 minutes before quitting time at night, workers may be seen sitting idly at their machines, while the shafting still runs on, walking about, chatting, or else making preparations to leave. Seven and one-half per cent of the total daily time is thus lost by many workers, of which 5 per cent is in the last hour.

CORROBORATION BY POWER CURVE.

The contrast shown in these observations is confirmed by a standard objective measure, the record of power consumption at each plant. This measure where applicable offers an exact mechanical index of the variations of output and on the point immediately at issue, namely, time lost in starting and stopping work, affords telling statistical evidence.

Obviously, the use of power consumption as a measure of performance is subject to certain limitations. It can not be used to gauge the large proportion of hand operations which still survive in industry, constituting, as we shall see, 50 per cent of the processes at the 8-hour plant and 75 per cent at the 10-hour plant. The power, moreover, used for wholly automatic machinery such as screw-machines, where the operator has no influence on the speed of production, offers no index of human working capacity, and must therefore be excluded from our consideration. But in all machine operations where speed is controlled by the operator, as in lathe and drill work, or where the operator manages the movement of the material, as in tool grinding, the consumption of power is a reliable gauge of activity.

In such operations records of power consumption were available at both the plants investigated, and the figures given in the Tables 9 and 10 for several standard operations at each plant may be held representative of time lost throughout the respective factories in starting and stopping work. These tables show how soon after starting the departments in question reached 90 per cent of average power, and how nearly up to the close of work the same percentage of power was maintained.

As a basis for the figures given, readings from the watt-meter were taken for six days at two-minute intervals, during the first and last half-hours of each spell, of the power supplied by the feeders to the departments under observation. From the total power load thus obtained the shafting load, which is constant and unrelated to output, and the lighting load were subtracted. The figures resulting give the variable power load and represent the amount of power actually used on the material.[1]

TABLE 9.—*Eight-hour plant, lost time shown by power records.*

Department.	Shift.	90 per cent of average power utilized.[2]	
		Number of minutes:	
		After starting.	Before stopping.
Radiator solder		6	8
Transmission gear cutting	Morning	6	2
Do	Evening	[3]6	[3]6
Crank shaft grinding	Morning	5	6
Do	Evening	18	12
Axle grinding	Morning	4	6
Do	Evening	4	4
Average		7	6.28

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[1] For details of method, see Use of Factory Statistics in the Investigation of Industrial Fatigue. Philip Sargant Florence. Columbia University Studies in History, etc. Longmans, Green & Co,, New York, 1918. For the method of comparing the constant and variable power loads at the two plants, see note at end of this chapter.

[2] Average power reckoned from readings every 15 minutes from 7.45 to 11.15 a. m. and from 1.45 to 5.15 p. m.

[3] Here at 6 minutes after starting and 6 minutes before stopping only 85 per cent of average power was in use.

TABLE 10.—*Ten-hour plant, lost time shown by power records.*

Feeder (section of building).	90 per cent of average power utilized.[1]			
	Morning spell, number of minutes:		Afternoon spell, number of minutes:	
	After starting.	Before stopping.	After starting.	Before stopping.[2]
1. Operating drills and lathes (for fuses), tool grinding..	10	7	6	21
2. Operating drawing machines (for bolts), tool grinding	6	7	4	17
3. Operating drawing machines (for bolts), operating drills and lathes (for fuses)...........................	14	9	8	(3)
4. Operating drills and lathes (for fuses)................	12	9	6	23
Average (weighted)...............................	12.2	8	6	21.5

[1] Average power reckoned as in Table 9.
[2] Work ceases at 5.55 p. m.
[3] More than 25; at 5.30 load is 75 per cent of average.

The contrast between the two plants is shown most strikingly in the figures for the final hour given in the right-hand columns. At the 8-hour plant 90 per cent of average power was maintained until 6 minutes on the average before the close of work; at the 10-hour plant more than 21.5 minutes before the close of work the percentage of average power had dropped below 90. In other words, work continued at the 8-hour plant practically under full power until 6 minutes before the end of the shift; at the other factory power began to decline three and one-half times as long before closing time—at exactly 5.30 p. m. when the investigators began afternoon readings, only 87 per cent of average power was in use in the entire building.

A less extreme but still marked contrast is shown in the time taken by the respective factories to begin the day's work. It takes only 7 minutes to reach 90 per cent of power at the 8-hour plant, but 12.2 minutes at the 10-hour plant.

Additional data secured for the 10-hour plant show the loss of time at the beginning of the afternoon spell to be decidedly less than that at the beginning of the day, and the loss of time at the end of the morning spell to be decidedly less than that at the end of the day. In starting the second spell it takes only half as long to reach 90 per cent of power (6 minutes) and in stopping before the noon break 90 per cent of power is maintained 8 minutes, as opposed to 21.5 before the close of work.

SOME TYPICAL OPERATIONS.

The results of an intensive study by stop-watch of actual time lost in certain operations at each plant are given in Tables 11 to 13.

TABLE 11.—*Ten-hour plant, time lost during working hours, day shift.*

Operation.	Number of observations.	Average time lost (in minutes) per man per day.				
		Starting.[1]	Stopping.[1]	Involuntary.	Voluntary.	Total.
Assemble cartridge clip (dexterous)	161	5	15	1	10	31
Planish seat (muscular)	46	21	43	11	42	117
Spin top cap (lathe machine)	87	19	24	[2]85	5	133
Dial press (miscellaneous machine), two operations	163	14	14	6	30	64
Mill percussion flash (stereotyped)	20	16	30	63	41	150

[1] These figures include starting and stopping in both spells.

[2] In the case of face and score train ring, the only other lathe operation not stereotyped, the involuntary time lost, according to 45 observations, was 38 minutes per man per day.

TABLE 12.—*Ten-hour plant, time lost during working hours, 12-hour night shift.*

Operation.	Number of observations.	Average time lost (in minutes) per man per day.				
		Starting.	Stopping.	Involuntary.	Voluntary.	Total.
Drill three holes (M)[1]	27	....	90	22	53	165
Drill four holes (S)[1]	56	....	62	11	4	77
Drill six holes (M)[1]	46	0.09	52	30	10	92.09
Face, drill, ream (S)[1]	53	0.19	69	43	14	126.19
Spin top cap (N)[1]	17	7	51	35	16	109

[1] Degrees of stereotyping are indicated by the capital letters beside the respective operations as follows: M=medium; S=slight; N=none.

TABLE 13.—*Eight-hour plant, time lost during working hours.*[1]

Operation.	Number of observations.	Average time lost (in minutes) per man per day.[2]				
		Starting.	Stopping.	Involuntary.	Voluntary.	Total.
First gear cutting, morning shift	291	....	....	15	....	15
First gear cutting, evening shift	262	....	....	15	....	15
Second gear cutting, morning shift	93	....	....	30	....	30
Foundry, ramming	18	....	....	50	7.5	57.5

[1] Losses calculated on 10-hour basis for purposes of comparison.

[2] Time lost in starting and stopping is not shown in this table for the reason that losses of less than 3 minutes were not recorded by the investigators.

Five typical operations at the 10-hour plant, chosen from the main groups of work, showed (Table 11), for an average of 95 observations, an average loss of 15 minutes in starting the two spells, varying in individual operations from 5 to 21 minutes. For the same operations the average time lost in stopping work, noon and night, made a much worse showing. The least time lost in the two stops was 14 minutes (dial press); the most (planish seat) was 43. In this latter operation the daily time lost in starting and stopping work averaged more than an hour.

On the night shift five operations show (Table 12) a much prompter start, as might be expected from the better coordination of men beginning work at 6 p. m. as compared with those beginning at 6 a. m., but a much more serious loss of time at the end of the shift. The loss of time in stopping work is more than twice as great as in the daytime, ranging in different operations from 51 minutes to an hour and a half, with an average of an hour and 5 minutes.

Three typical operations studied at the 8-hour plant yielded (Table 13) no figures because losses of less than three minutes in starting and stopping were not recorded by the investigators, and no losses of more than three minutes occurred at the plant.

TIME LOST THROUGHOUT THE DAY.

Looking now at the time lost throughout the day at the respective factories, we find the comparison to be still more unfavorable to the 10-hour plant. The heading in the tables, "voluntary" and "involuntary", represents, respectively, time deliberately wasted by the operatives and time lost by waiting for material, failure of power, breakage of machines, and other causes not in the workers' control.

At the 8-hour plant in the three operations studied (one on two shifts) (Table 13), we find no time whatever noted as voluntarily lost except in one. In this, the heavy operation of ramming molds, the time lost was only 7½ minutes. This remarkable record is rendered still more noteworthy by contrast with the 10-hour plant where "voluntary" time lost averages for the five operations studied in Tables 11 and 12, 26 minutes in the day shift and 19 at night. Though the loss sinks in the best operations to 4 and 5 minutes, it rises in others to 41, 42, and even 53 minutes.

"Involuntary" time lost is a test of the management rather than the worker, depending on power, routing, flow of work, supply of material, etc. It is of special interest here in view of the influence it apparently exerts on the voluntary loss of time. From the figures given in our tables it appears that voluntary time lost tends to increase as involuntary delay decreases, and vice versa. Thus, where the involuntary delays have been long ones, as in spin top cap on the day shift at the 10-hour plant (85 minutes, see Table 11), the workers are rested and eager to make up their piece wages; the voluntary time lost is accordingly very slight (5 minutes). In assemble cartridge clip, on the other hand, where the involuntary delay is only 1 minute, the time deliberately lost in resting is naturally longer (10 minutes). In the more taxing operation of dial press, the workers lose 6 minutes involuntarily but take 30 minutes of deliberate rest. Planish seat, the heaviest operation studied, shows a loss of only 11 minutes for involuntary delays, but of 42 minutes in voluntary time lost. This serious loss, together with the 43 minutes lost at the close of work, emphasizes the fatiguing nature of the operation. The only case on the day shift where "voluntary" does not vary inversely with "involuntary" time lost is in the stereotyped operation of mill percussion flash. Here though more than an hour is lost in involuntary delays, and the operation is no heavier than spin top cap, the voluntary time lost is very high. This loss of nearly three-quarters of an hour together with the waste of 30 minutes at the close of work affords some measure of how far, in stereotyped operations, men work below capacity.

In three out of five operations on the night shift, half to three-quarters of an hour's involuntary rest is supplemented by a quarter hour or less of voluntary breaks. In drill three holes, where the involuntary delay is only 22 minutes, the workers compensate themselves by 53 minutes of deliberate rest. Drill four holes shows the least loss of time, either voluntary or involuntary, throughout the night. But here, as in the other operations on the night shift, the question is complicated both by degrees of stereotyping and by the tendency of the workers to concentrate waste of time in the last hours of the shift by stopping work before the closing hour.

Thus, through involuntary or voluntary delays, the 10-hour workers tend to work below capacity. Striking evidence on the other hand of the 8-hour men's tendency to work to capacity is offered by the fact that in two of the three operations studied no time whatever was lost in voluntary pauses,[1] and in the third, ramming molds, the most fatiguing operation in the factory, only 7½ minutes.[2]

Total time lost at the 8-hour plant was 57.5 minutes in the operation making the worst record. In the other two operations studied it was 30 and 15 minutes, respectively. At the 10-hour plant the total time lost in the day shift was half an hour in the operation making the best record, more than an hour in another, nearly two hours in a third, and more than two hours in a fourth and fifth.

In the night shift, total lost time ranged from an hour and a quarter to two hours and three-quarters.

These extraordinary differences can not be explained by differences in excellence of management at the two plants; they point to a universal tendency. The "tradition of slowed labor" to which the British Health of Munition Workers Committee ascribes the "conscious or unconscious slackening of effort . . . during working hours of improper length"[1] is accountable in large part for lost time as well as stereotyping.

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[1] That is, no periods of as much as 3 minutes or more. No record was made by the investigators of time losses below 3 minutes.

[2] Time losses at the 8-hour plant are calculated on a 10-hour basis for purposes of comparison with those at the 10-hour plant.

NOTE ON METHOD OF COMPARING POWER CONSUMPTION AT THE EIGHT-HOUR PLANT AND THE TEN-HOUR PLANT.

In the attempt to determine the comparative amount of time lost at the beginning and end of work by the workers at the 8- and the 10-hour plants a study was made in each of the power curve as an index of activity. This study was limited in two ways. The power curve can obviously be used as such an index only in machine operations where the workers' activity influences the speed of the machinery; such operations constitute only about 25 per cent of all activities at the 10-hour plant (see pp. 137–8), and about 50 per cent of those at the 8-hour plant (see p. 73). Power consumption was studied at each plant, moreover, only in certain representative departments or operations. In spite of these limitations, however, the curve of power consumption in the departments studied may fairly be considered indicative of each factory's respective tendency to work up to or below capacity.

At the 10-hour plant power consumption was studied, among other departments, in three largely occupied with uniform machine operations of the lathe type. Readings from the watt-meter were taken every quarter of an hour during the day. In 1917 the percentage of total power used for driving the shafting, averaged through the day and exclusive of the lighting load, was as follows for the three departments respectively: 84 per cent, 74 per cent, 71 per cent; or, averaged for the three, 76 per cent. The variable load (the percentage of power varying with activity or output), was accordingly 24 per cent.

At the 8-hour plant power consumption was studied on three representative operations of the lathe type of machines, namely: rear axle housing, axle grinding, and crank shaft grinding. These are machine operations heavier than those in the departments of the 10-hour plant just quoted, but otherwise of similar type. The percentage of total power used in driving the shafting for these operations averaged through the day and exclusive of the lighting load, was found to be as follows:

Rear axle housing, morning shift, 33.2 per cent; evening shift, 35 per cent.

Axle grinding, morning shift, 38.5 per cent; evening shift, 41.5 per cent.

Crank shaft grinding, morning shift, 35.5 per cent; evening shift, 39.3 per cent.

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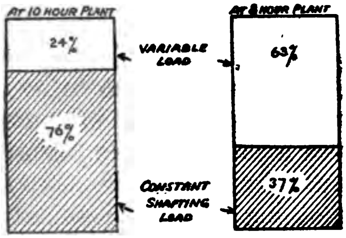
[1] Health of Munition Workers Committee, Interim Report, 1917, Industrial Efficiency and Fatigue, p. 12.

The average shafting load for the three operations was therefore the average of all these six percentages, 37 per cent, and the average variable load 63 per cent.

The marked disparity of the proportions of shafting to variable load at the two factories is strikingly shown in the following diagram.

DIAGRAM 1.—*Diagram showing power consumption.*



The rectangles represent total power consumption, the hatched areas the shafting or constant load, and the white areas the variable load.

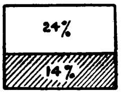
It is clear that the different ratios of shafting to variable load at the two plants shown in the diagram make comparison of power as an index of activity unfair. A fluctuation of 10 per cent in the total power load for example will involve nearly one half the machine activity of the 10-hour plant but only one-sixth of the machine activity of the 8-hour plant. To secure a just basis for comparisons of power at the two plants we must evidently equalize the proportions of shafting to variable loads. For this purpose the shafting load at the 10-hour plant must be reduced to the same proportional relation to the variable load that the shafting load bears to the variable load at the 8-hour plant. This reduction of the shafting load will be determined by the following simple proportion:

Revised shafting load : 24 : : 37 : 63.

Then the revised shafting load at the 10-hour plant equals 14.

The new total load is now 38 per cent (14 per cent + 24 per cent) of the original total load, and the new shafting load, 14 per cent, is 37 per cent of the total (14=37 per cent × 38). The new shafting load therefore bears the same relation to the new total as the shafting does to the total at the 8-hour plant.

DIAGRAM 2.—*Diagram showing power consumption at 10-hour plant as approximated to basis of 8-hour plant.*



Thus the proportion of power used in shafting at the 10-hour plant is reduced to the same proportional basis as that used at the 8-hour plant, and fluctuations in the total power load assume the same degree of significance for each factory's activity.

CHAPTER 4.

STEREOTYPED OR RESTRICTED OUTPUT.

At the 10-hour plant artificial limitation of output is widely prevalent. At the 8-hour plant output varies more nearly with individual capacity.

Besides the various composite and single curves thus far represented for the two plants, erratic curves are shown by certain processes at the 10-hour plant quite unlike the rest in general outlines. These curves tend to reach their highest point sometimes in the last hour of the morning spell but usually late in the afternoon. They are the more striking because nothing like them is found at the 8-hour plant. Examples of five such operations are presented in Table 14 and chart 22.

The kind of curve in question is determined by a practice widely prevalent at the 10-hour plant, that of voluntary fixing of output. Under this system, a standard day's performance is tacitly set between foreman and workers, and is followed day after day. This stint is the amount expected of the worker, and no questions are asked if it is achieved. Such an output may be called "stereotyped."

EXTENT OF STEREOTYPING.

This limitation of output has been traced in more than half of all the departments at the factory where the output is capable of uniform measurement. It is particularly noticeable in the fuse-making rooms, the primer house, and the blanking room. So widespread, indeed, is its influence that operations at the factory should perhaps be classed as more or less stereotyped rather than as stereotyped and non-stereotyped. Care was taken in the investigation, however, not to include in the general studies of output those processes in which production was to any marked degree thus limited.

STEREOTYPING IN OPERATIONS STUDIED AT TEN-HOUR PLANT.

I. Great:
  - Drill diagonal holes.
  - Drill flash holes.
  - Mill percussion flash.
  - Drill and tap for percussion end.
  - Bevel train ring (lathe).

II. Medium:
  - Drill 3 holes.
  - Drill 6 holes.

III. Slight:
  - Drill 4 holes.
  - Graduate train rings.
  - Retap top cap.
  - Face, drill, and ream.
  - Buffing.
  - Face and score train ring.

IV. None:
  - Form springs (dial press).
  - Cover fabric (dial press).
  - Spin top cap.
  - Footpress assembly.
  - Weigh brass samples.
  - Planish seat.
  - Charging buttons.
  - Painting screw-holes with lacquer.
  - Solder.
  - Fuse assembly.
  - Assemble clips.

A CHARACTERISTIC EXAMPLE OF STEREOTYPING.

One operation on the day shift, drill and tap for percussion end, may serve to give a typical picture of the curve of stereotyping (chart 21). This complicated process, which drills, hollows, and polishes the various interior cavities of the fuse body, illustrates well the erratic nature of the curve in question. It is perhaps the most exacting of the lathe operations at the 10-hour plant; a 6-tool capstan lathe is used in the process, and for each separate detail of the work the operator must with his left hand revolve the capstan one-sixth of a circle and with his right pull forward the lever that applies the proper tool. Yet the curve, rising slowly through the morning, and dropping sharply between 2 and 3 o'clock, reaches its maximum for the day in a final spurt between 4 and 5, just preceding the heavy fall of the last hour. The explanation generally given is that the workers, working deliberately below capacity through the day, must spurt to make the day's required output and usually do so before the very last hour. The height of the peak shown so late in this operation indicates the high level of energy remaining toward the end of the day's work. The curve of this operation approximates most closely to the general composite curve of stereotyped operations (chart 22).

TABLE 14.—*Ten-hour plant,*

Operation.	Number of observations.	Starting time of shift.	Period of study (days).	(*a*) Number of units; (*b*) Index numbers.[1]	Average output observed each working hour.		
					First.	Second.	Third.
Bevel train ring[2]	80	7 a.m.	16	(*a*)	204	334	327
				(*b*)	57.8	98.8	91.9
Drill two diagonal holes	110	...do...	11	(*a*)	283	285	272
				(*b*)	98.3	99.0	94.4
Drill two flash holes	110	...do...	11	(*a*)	289	272	270
				(*b*)	100.0	94.1	93.4
Mill percussion flash	33	...do...	11	(*a*)	699	628	621
				(*b*)	100.0	89.8	88.8
Drill and tap for percussion end	33	...do...	12	(*a*)	439	453	458
				(*b*)	81.3	83.9	84.8
Average index numbers					87.4	92.1	90.7

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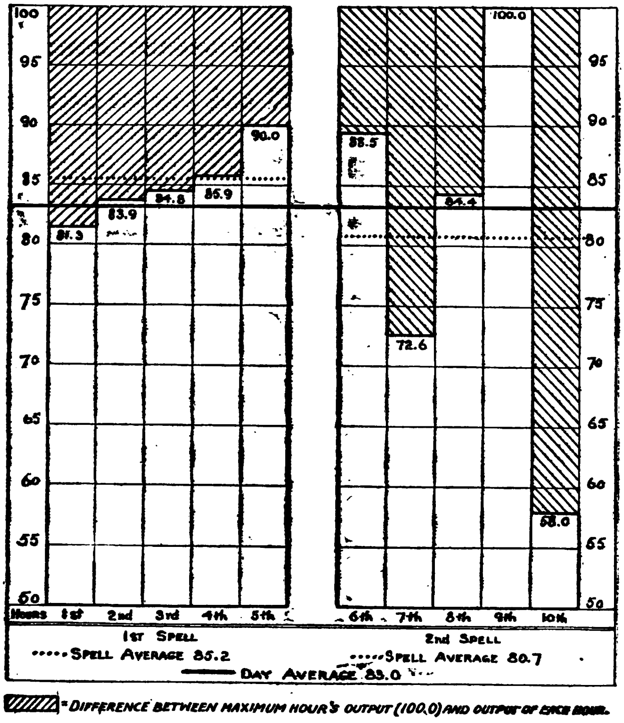
[1] Index number=percentage variation from maximum; maximum=100.

[2] Small size.

CHART 21.—*Index numbers showing percentage variations of hourly output from maximum hour's output.*

TEN-HOUR PLANT—DRILL AND TAP FOR PERCUSSION END.

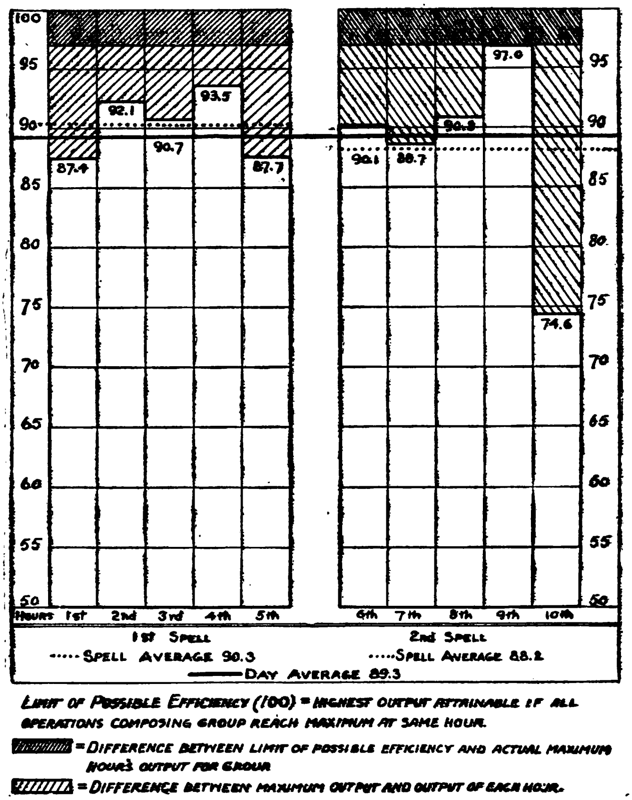


stereotyped operations.

Average output observed each working hour.										Ratio of second spell to first spell (in per cent).
Fourth.	Fifth.	Average for spell.	Sixth.	Seventh.	Eighth.	Ninth.	Tenth.	Average for spell.	Average for day.	
356	318	308	247	336	340	351	238	302	305	
100.0	**89.3**	**86.5**	**69.4**	**94.4**	**95.5**	**98.6**	**66.9**	**84.9**	**85.7**	98
274	253	273	279	271	277	288	239	271	272	
95.1	**87.8**	**94.8**	**96.9**	**94.1**	**96.2**	**100.0**	**83.0**	**94.1**	**94.4**	99
284	258	275	289	281	266	288	232	271	273	
98.3	**89.3**	**95.2**	**100.0**	**97.2**	**92.0**	**99.7**	**80.3**	**96.8**	**94.5**	99
616	573	627	668	595	601	606	591	612	620	
88.1	**82.0**	**89.7**	**95.6**	**85.1**	**86.0**	**86.7**	**84.5**	**87.5**	**88.7**	98
464	486	460	478	392	456	540	313	436	448	
85.9	**96.0**	**85.2**	**88.5**	**72.6**	**84.4**	**100.0**	**58.0**	**80.7**	**83.0**	95
93.5	**87.7**	**90.3**	**90.1**	**88.7**	**90.8**	**97.0**	**74.6**	**88.2**	**89.3**	98

CHART 22.—*Index numbers showing percentage variations of hourly output from limit of possible efficiency.*

TEN-HOUR PLANT—STEREOTYPED OPERATIONS.



PREVALENCE OF STEREOTYPING: EXAMPLES.

The highest proportion of stereotyping has been found in those machine operations where control over the starting and stopping of the machine is vested in the operator, usually by means of a hand or foot lever, and where the work consists simply in the application of a single tool to the material. In gauging and inspecting fuses, as well as in certain other fuse operations, stereotyping is extremely common. In all these processes the rigidity of output is remarkable, the same number of units being produced day after day or night after night by workers. Thus in the operation of drilling holes in the fuse, known technically as 53 drill, exactly the same number of fuses, namely, 3,600, were drilled night after night for a whole week by each of 16 different workers. In the day shift 3,000 was the stereotyped output, the rate of production thus being exactly the same as by night, 300 an hour. Seven operators were studied for five days, and in all 35 observations 300 fuses were drilled per hour. In two cases the full 10 hours were not worked, but in spite of this the rate was maintained and an exactly proportionate output was produced.

The operation of drilling two diagonal and two flash holes, which was made the subject of an hourly output observation, showed a surprising regularity in the day's and even in the spell's output. One hundred and sixty-three observations were made in all, on 9 or 10 batteries of two operatives and a jig-boy each for 17 days. In 99 cases an output of 2,600 was produced per day and exactly 1,300 in each spell; in 5 cases 2,600 were produced per day, but they were unequally distributed over the spells; in 23 cases 1,300 were produced in one of the spells but not in the other; and in only 36 cases, 22 per cent, was there no stereotyping. Fifteen of these cases occurred on Saturday, and with many of the remainder prolonged machine trouble or lack of materials accounted for the deviation from type. It should be noted that almost all deviations were below the stereotyped output rather than above.

In the work of gauging and inspecting fuses, the fact that the girls employed work in batteries and contribute to a joint product, might explain a more or less uniform pace. This explanation, however, does not account for the striking similarity of output on successive days. In the operation known as gauging 5, five girls out of six had an output of 1,315 every full day of one week that was studied; in gauging Pl S pins the three girls studied individually for a week produced outputs of 1,750 on 14 out of 15 occasions. Similarly, in inspecting 20 three girls produced 720 per day on 13 out of 15 occasions; in gauging S pins three girls produced 1,537 per day on 14 out of the 15 occasions; in gauging 1 three girls produced exactly 1,352 a day on 11 out of the 15 occasions; and so on.

In forming the large end of fuses at a capstan lathe, where each man worked individually, 15 men were studied for 3 months in the summer. One man finished exactly 1,000 fuses on 44 nights out of 45, another the same figure on 47 nights out of 50, another on 40 out of 49, another on 46 out of 51. Among the remaining men the figure 1,000 was produced for 88 nights out of 105.

CONTRAST OF STEREOTYPED OUTPUT AT TEN-HOUR PLANT WITH VARIATION OF OUTPUT AT EIGHT-HOUR PLANT.

By comparing the records of groups of workers in comparable operations at the two factories, this extraordinary rigidity of production in stereotyped processes may be effectively contrasted with the variation of output according to individual capacities at the 8-hour plant. Thus, for instance, the records of a group of 21 men employed at lathe work, forming the small end of the fuse, were obtained at the 10-hour plant during two periods of two weeks each (Table 15). The median[1] output per day was 835.5 fuse ends during the first fortnight and 839.3 fuse ends during the second. How slightly the average individual output deviated from the median is shown by an interquartile range of only 4.2 and 6.1, respectively, that is, 0.50 and 0.73 per cent of the median.

TABLE 15.—*Ten-hour plant, output of stereotyped operation.*

FORM SMALL END OF FUSE ON LATHE.

Check number of worker.	Dec. 31, 1917–Jan. 17, 1918.		Jan. 22–Feb. 8, 1918.	
	Number of observations.	Average output per day.	Number of observations.	Average output per day.
10353	14	833.1	8	840.0
10355	14	835.0	12	846.7
10358	13	831.0	12	828.9
10361	14	836.9	12	833.9
10365	13	833.4	12	839.3
10366	12	836.2	12	840.0
10367	11	836.9	11	838.9
10384	14	840.4	10	845.4
10420	14	824.1	12	831.6
10440	14	839.1	10	838.9
10468	8	832.5	10	840.0
10484	13	700.4	7	745.1
10489	8	835.3	8	840.0
10493	14	830.2	12	831.1
10496	13	837.9	12	840.0
10508	14	851.1	7	841.5
10505	11	835.5	11	840.0
10510	9	846.7	10	841.1
10547	14	837.3	10	838.9
10551	11	833.4	8	838.4
10560	11	837.0	8	824.1
Total	259		214	
Median		835.5		839.3
Quartiles:				
Upper		837.3		840.0
Lower		833.1		833.9
Interquartile range		4.2		6.1
Per cent of median		.50		.73

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[1] When all records are listed in the order of the magnitude of their amounts, as from lowest to highest, the median is the amount indicated by the middle record; the lower quartile is the amount indicated by the middle record of the lower half of the series; the upper quartile the amount indicated by the middle record of the upper half of the series. The interquartile range is the distance between the amounts indicated by the two quartiles.

In contrast to these records, the varying output of workers in a different lathe operation at the 8-hour plant stands out strikingly (Table 16). 17 workers grinding crank shafts were observed during a period of 7 weeks, 415 observations being made. The median output was 198 crank shafts. The deviation from the median is shown by an interquartile range of 17, or 8.59 per cent of the median as contrasted with 0.50, and 0.73 per cent of the median at the 10-hour plant.

TABLE 16.—*Eight-hour plant, output of non-stereotyped operation.*

CRANK SHAFT GRINDING ON LATHE.

Check number of worker.	Sept. 15–Nov. 5, 1917.	
	Number of observations.	Average output per day.
2614	12	200
2685	34	198
2702	24	216
2716	25	199
2853	18	182
2883	26	204
2895	16	177
3055	17	183
3058	33	200
3082	28	198
3092	30	174
3105	28	192
3136	22	209
3170	25	193
3212	15	172
3219	31	190
3268	31	207
Total	415	
Median		198
Quartiles:		
Upper		200
Lower		183
Interquartile range		17
Per cent of median		8.59

Twenty-nine workers grinding axles at the 8-hour plant were also studied during two different periods of time, over 700 observations being made (Table 17). The median output was 398 axles. The deviation from the median is shown by an interquartile range of 26; that is, 6.53 per cent of the median, as contrasted again with percentages of 0.50 and 0.73 at the 10-hour plant.

TABLE 17.—*Eight-hour plant, output of non-stereotyped operation.*

AXLE GRINDING ON LATHE.

Check number of worker.	Sept. 19–Oct. 13 and Oct. 29–Nov. 10, 1917.	
	Number of observations.	Average output per day.
4318	32	410
4356	26	398
4419	31	407
4370	19	387
4354	29	390
4342	28	377
4063	8	381
4182	9	380
4200	32	413
4223	29	394
4238	29	307
4465	22	401
4289	26	406
4282	6	374
4402	17	391
4215	31	392
4220	27	400
4361	28	402
4392	31	411
4232	29	416
4287	33	347
4350	33	428
4395	30	408
4452	30	399
4426	24	425
4276	28	392
4221	22	414
4373	16	382
4206	24	370
Total	729	
Median		398
Quartiles:		
Upper		408
Lower		382
Interquartile range		26
Per cent of median		6.53

EVILS OF STEREOTYPING.

The basic objection to such artificial limitation of output is its disregard of the individual capacity of the worker. Instead of allowing free play to individual powers, this practice sets a rigid standard to which the worker must conform, either checking high capacity for work or speeding up low capacity—both unnatural processes. As a matter of fact, its tendency is to level output, as we have seen, to the measure of inferior capacity. The workers have their stint clearly in mind and, if they find their output progressing fast, they may deliberately slow down. In the drilling of two diagonal and of two flash holes the usual custom is, as we have seen, to produce half the desired output in each five-hour spell. One foreman reports, however, that on night shift workers get ahead in their output on the first spell from 6.20 to 12 o'clock and are inclined to "go easy" in the second spell, 12.20 to 6.40. On the other hand, if the workers find they are getting behind they will urge themselves on by a series of spurts and thus tire themselves out for the next working period.

SOME EXAMPLES OF SPURTING.

The loss suffered by the factory from the prevalence of stereotyping is indicated by the extraordinary rise in the rate of output when, through some involuntary stoppage of machines or delay of work, the workers find themselves threatened by a loss of normal piece-work wages. In the operations studied there is no complete mechanical limit to output. In the drilling operation known as 53 drill the ratio between the length of time during which the operative can choose his own pace and the length of time of actual contact of tool and material, fixed by the cutting qualities of the material and the danger of breaking the tool, is as two to one. In the spin top cap operation the ratio is slightly more than two to one. Both figures were obtained by repeated stop-watch observations. The possibility of the worker's increasing his pace at will in spite of this partial mechanical limit is seen in the spurts that take place when the first part of the hour is for any reason wasted. Often during the remainder of the hour the pace is at 150 or more per cent of the usual rate. For instance, in drilling diagonal and flash holes the day's output is stereotyped at 2,600, i. e., at 260 per hour; but in the week ending August 4 we find one worker whose drill was broken between 2 and 2.30 o'clock working between 2.30 and 3 at the rate of 483 an hour, almost double her usual pace (86 per cent increase), another worker who awaited materials between 7.15 and 7.30 working the remainder of the hour at the rate of 339 per hour, and another who voluntarily left her bench for a quarter of an hour working the remainder of the hour at 375 per hour. These are not extreme cases but merely samples chosen at random.

To find the usual average increase in pace after an enforced or voluntary stoppage of work, a study was made in the stereotyped operation of drilling flash and diagonal holes of every case where work stopped for a quarter hour or more within the first half of the hour. Twenty-nine such cases were found, and in the hours in which the stop occurred the output per hour, when corrected, that is, compensated for the time lost by the interruption, averaged 370 pieces per hour, i. e., 142 per cent as much as the stereotyped production of 260 per hour. In the operation of milling the percussion flash the hourly output rate after a stoppage of a quarter hour or more, taking the average of all the 13 cases found, was 770, while the stereotyped hourly output was 565. The worker was thus able to work, for half an hour or more, at a rate 136 per cent as fast as the stereotyped rate.

The same kind of spurt is also produced before a definitely expected interruption of work. Regularly at a certain time on every Thursday work is stopped for a quarter of an hour while employees receive their pay envelopes. During the remainder of the hour, whether it is before or after the stoppage, the rate of output is so much in excess of the average that in the tables this hour's excess output had to be cancelled and the disturbing factor of pay thus eliminated. In the stereotyped drill two diagonal and two flash holes on one of the three Thursdays observed, the hour 11 to 12, when payments were made, showed an output rate as high as 361 against the usual 260 per hour (39 per cent increase). The stereotyped output seems easily exceeded to compensate for an interruption which is expected to occur as well as to make good an interruption of work.

CAUSES OF AND REMEDIES FOR STEREOTYPING OF OUTPUT.

Thus the normal level of output in these stereotyped operations runs from 24 to 46 per cent below the peak of the highest spurt. These high spurts are frankly exceptional, lasting only part of an hour, paces not to be sustained throughout the working day; yet it is none the less undeniable that a much closer approximation to capacity might reasonably be possible.[1]

Organized labor can not be held accountable for this limitation of output, for the 10-hour plant has few union workers. Nor would it be just to attribute it solely to the management of an individual factory. In a large industrial district such as that about the 10-hour plant the attitude of the workers in any one factory is formed not so much by the policy of any one factory as by the general policy of all the factories of the district. Within any industrial district labor is extremely mobile and the suspicion or confidence generated in one plant will soon affect the employees in all other factories of the neighborhood. It is probable that the stereotyping at the 10-hour plant is due to a general attitude toward employers, which has similar reactions in other plants.

One of the underlying causes of limiting output is undoubtedly the fear of the worker, too often justified by experience, that as soon as he increases his output and makes high wages the management will reduce the piece rate. Under these circumstances the worker naturally prefers to maintain his slower rate of output, for he will gain no advantage from working any harder.

In like manner the wage system prevailing only a year before the investigation at the 10-hour plant, the so-called "premium bonus" system, under which the higher the output the lower was the rate paid per hundred, may, by its logical discouragement of effort, have been the origin of the present artificial limitation of production. The same system formerly used in one of the largest munition factories in England resulted, according to official report, in a similar restriction of output, with a similar recurrence of exactly the same output, at successive periods of observation, by the same workers.[1]

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[1] Since the increased speed is kept up only to make up for time lost and to bring up the hourly output to the desired figure, the higher rate of speed during part of the hour does not affect the hourly output curves and does not show in the tables or charts of stereotyped operations.

To remedy conditions leading to such restriction of output must be a prime aim of an efficient management. And first for this purpose there should be an absolute assurance to the employees that there will be no cutting of piece rates. This assurance once given should exclude the possibility of any subterfuges to produce the same result of lower wages. Thus, if earnings are considered abnormally high at any one operation, the management is sometimes tempted to abolish that particular type of operation and substitute another giving the same product, this time on a lower piece-rate basis. This artifice is not uncommon in industry; it has been used at the 10-hour plant; it is well known to the worker; and in the long run it only reacts against the employer. Nothing should be done to undermine the confidence of the worker that an increase of output will lead to higher wages.

In addition to obtaining the confidence of workers in the matter of piece rates, it is also important for the management to provide the proper facilities in the way of raw materials, machines, routing of work, etc., so as to enable the worker to utilize his working capacity to the fullest extent he may desire. Without such planning and provision on the part of the management, it is clearly impossible for the workers even with good will to come up to capacity.

The fundamental cause for limitation of output, however, lies deeper. No group of workers could continue, without physical disaster, to work at full capacity for a stretch of 12 hours at night or 10 hours in the daytime, not to mention the 3 hours overtime irregularly worked at the 10-hour plant. Low speed, wasted time, limited output are in large part the worker's automatic defense against exhaustion, against the overstrain of excessive hours of labor.

On this point the British Health of Munition Workers Committee has acutely said: "In so far as hours of work in excess of those suitable for maximal efficiency have been imposed during the last two or three generations of modern industry upon the workers, a tradition of slowed labor must necessarily have arisen, probably in large part automatically, as a kind of physiological self-protection. Without some conscious or unconscious slackening of effort indeed during working hours of improper length in the past, the output might have been even more unfavorable than it is known to have been for the hours of work consumed."[2]

For this "tradition of slowed labor", for the stereotyping which has been illustrated at the 10-hour plant, the cure is, above all, the reduction of hours of labor.

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[1] Health of Munition Workers Committee, Interim Report, 1917. Incentives to Work with Special Reference to Wages, p. 72.

[2] Health of Munition Workers Committee, Final Report, 1918, p. 18.

CHAPTER 5.

INDUSTRIAL ACCIDENTS.

THE CAUSATION OF ACCIDENTS.

This chapter deals with the human factor in industrial accidents and is not concerned with the part played by machinery or mechanical agencies.

The probable relation of fatigue to the causation of accidents has attracted attention from the first days of the modern industrial system nearly a century ago. To "overfatigue and lassitude" the increase of accidents during the day was ascribed as early as 1831 in the report of the first British Children's Commission. While no special studies of the distribution of accidents were made during the next 50 years, fatigue was generally accepted as being the cause of the rise of accidents observed in the later hours of the morning and afternoon. With the adoption in Germany in 1884 of a comprehensive system of accident compensation, the reporting of the hours of incidence of accidents first received serious attention and was indeed made compulsory by law. Special studies published by the Imperial Insurance Office at 10-year intervals, beginning in 1887, gave the hourly distribution of accidents and in 1907 made a first attempt to classify accidents by the hours previously worked by injured persons. Following these initial studies, similar investigations were made during the first decade of the present century in France, England, Belgium and Italy. In all of these inquiries it was generally held that accidents varied inversely with working capacity, or that fatigue was the chief determinant of the accident rate.

In the United States few statistics were published before 1910. In 1911, however, an important contribution to the study of accidents and accident causation was made by a report of the United States Bureau of Labor Statistics on accidents in the metal trades.[1]

A new factor, speed of production, was introduced in this report for the first time as the primary cause of the variation of accidents. According to this "provisional hypothesis," "the immediate cause of a variation in the accident rate through the hours of the day is the varying rate of activity. Fatigue then comes in as an important secondary factor serving sometimes to increase the accident rate, sometimes to decrease it."

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[1] U. S. Bureau of Labor Statistics, Report on the Condition of Woman and Child Wage Earners in the United States, vol. 9: Employment of Women in the Metal Trades, 1911, pp. 73-101.

Yet this accident rate is a "complex product." "Any increase of speed of operation,'' says the report, "unless accompanied by some counteracting safeguard, may be expected to show a higher accident rate. It is evident that in the interrelation of influences acting upon the situation now one and now another may be dominant. The most constant factor will be fatigue. It will be present in varying proportion in every case. It may act with the tendency to increase speed to produce a greater number of accidents. It may in the end become so pronounced that speed is reduced and the accident rate lowered."[1]

The accident rate will then roughly follow the rate of output. And in so far as the variations of output are associated with fatigue, fatigue will directly or indirectly influence the accident rate.

The writer of the report, Chaney, saw clearly, however, that in order to substantiate this theory fuller statistics were necessary than those at his disposal, and for the first time he drew attention to the fact that no definite conclusions could be reached without a study of both accidents and production in the same establishment. For such a study the necessary data were wanting in 1911, and for this reason it was impossible to verify the essential truth of the new hypothesis.

This first effort to relate speed of production to fatigue in a tenable hypothesis was not continued by later investigators.

In a further study of accidents in the iron and steel industry published by the United States Bureau of Labor Statistics in 1913,[2] the same lack of accident and production figures for the same plant prevented the establishment of any definite conclusions bearing upon the relation of production, accidents, and fatigue. "It is clear," the report concludes, "from the limitation of the material that the answer to these questions can not yet be made."

The British Association report of 1915 on "The Question of Fatigue from the Economic Standpoint,"[3] accepted the influence of speed of production as well as fatigue on accidents and made the significant suggestion that in studying the causes of accidents the absolute distribution of accidents is less important than their distribution per unit of output. For such a correlation, however, that investigation, like the earlier ones, offered no sufficient data.

But in the most recent British investigation, speed of production has been emphasized to the virtual exclusion of fatigue.[4]

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[1] Op. cit. p. 100.

[2] Report of the United States Department of Labor on Conditions of Employment in the Iron and Steel Industry in the United States, vol. 4. Accidents and Accident Prevention. Senate Document No. 110, 62d Cong., 1st sess. Washington, 1913, pp. 152-156.

[3] Transactions of the British Association for the Advancement of Science, Section F. The Question of Fatigue from the Economic Standpoint. P. Sargant Florence, Organizing Secretary. Manchester, 1915, p. 23.

[4] Health of Munition Workers Committee, Memorandum No. 21, 1918. An Investigation of the Factors Concerned in the Causation of Industrial Accidents, H. M. Vernon, M. D.

According to Dr. Vernon, writing under the auspices of the Health of Munition Workers Committee, accidents vary in the main with output. "Speed of production," he writes, "is the essential factor in accident causation." "Fatigue has but little influence in the causation of accidents in men," and even in women, except in such extreme cases as the so-called "fatigue period" of 75 hours per week, is of "only moderate importance." An important contribution made by Vernon is the new suggestion that the accident curve will follow the output curve in general form but may exceed it in steepness, accidents, it may be, rising 5 or 10 times as fast as output.

A further step toward the correlation of accidents with output is taken in his report by placing in physical juxtaposition on the same charts the accident and output curves for the establishments studied.

That Vernon's conclusions are only partly true, because based on output curves which are not fully representative, we shall show subsequently in detail. Since his investigation deals in the main only with machine work, he has based conclusions on a type of work where output least registers the fall of working capacity, and where accordingly his theory of the dominant influence of speed of production is best illustrated. Instances in which fatigue is clearly registered even in his own curves appear to have been overlooked.[1]

In 1918, in its study of the safety movement in the iron and steel industry, the Bureau of Labor Statistics attempted to correlate accidents and output in accordance with the suggestion of the report of 1911. Statistics of both accidents and output were now available for the same establishments. These were placed in juxtaposition in charts and tables, though no attempt was made to determine their exact relation. Unfortunately the output data furnished by the factory records chosen were of so special and peculiar a character as to eliminate the factor of fatigue from the start. Arguing from these new data, the Bureau of Labor Statistics withdrew fatigue from its hypothesis and offered an explanation based on speed of production and imperfect coordination.[2]

The writers of this report, Chaney and Hanna, find no demonstrable relation between fatigue and accidents but suggest a tentative or "provisional" explanation of the accident curve and its relation to the curve of production. According to this explanation, imperfect coordination, together with the effort for increased speed, causes the rise of production in the early hours of the morning spell to be accompanied by a much steeper rise of accidents. As fuller coordination is reached, accidents fall while output continues to rise. After the noon break it is held that the "period of adjustment is shorter," and the period of "relatively good coordination is longer." Hence the accident peak is reached earlier than in the morning and "naturally the afternoon product is larger."[1]

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[1] See Note C at end of this chapter, The Theory of Accidents Advanced by the Health of Munition Workers Committee.

[2] U. S. Bureau of Labor Statistics, Bulletin No. 234, June, 1918. The Safety Movement in the Iron and Steel Industry, 1907 to 1917, pp. 154-161.

The writers, indeed, admit that while "the fatigue factor can not be identified in these curves," it "does not follow that it has no influence." They confine this probable influence of fatigue, however, to "the period of recoordination in the morning" (p. 163).

Meantime, in the year 1913, the method of correlation in determining accident risk had been successfully applied on a yearly basis by a report of the United States Bureau of Mines on accidents in coal mines in the United States and foreign countries.[2]

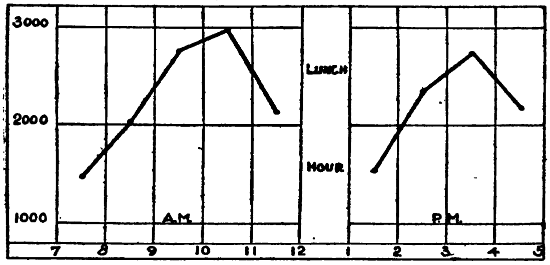
This report presented an exact correlation of accidents and output during the years studied in the coal-mining industries of ten important coal-mining countries. Tables and charts were given throughout the report showing production, number employed in the industry, and death rates per 1,000 employed and per 1,000,000 tons mined. This correlation gave striking proof of the variation of accidents with speed of production from year to year, but threw no light on the relation of speed and fatigue to the daily distribution of accidents.

MISLEADING NATURE OF THE ABSOLUTE ACCIDENT CURVE.

While various attempts have thus been made to correlate accidents and output, the general basis of conclusions, so far as the hourly distribution of accidents is concerned, has remained the absolute accident curve, that is, the curve plotted from the total number of accidents occurring hour by hour throughout the working day. This curve, made familiar by previous investigations, may be illustrated by charts 23 and 24, which are reproduced from the report of the British Association already cited.[3]

CHART 23.—*Distribution of accidents during full working hours.*

TOTAL OF INDUSTRIES IN OHIO, 1914.



Plotted from figures given by the Ohio Industrial Commission, Department of Investigation, Report No. 4, 1914.

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[1] See Note D at end of this chapter, The Theory of Accidents Advanced by the U. S. Bureau of Labor Statistics, 1918.

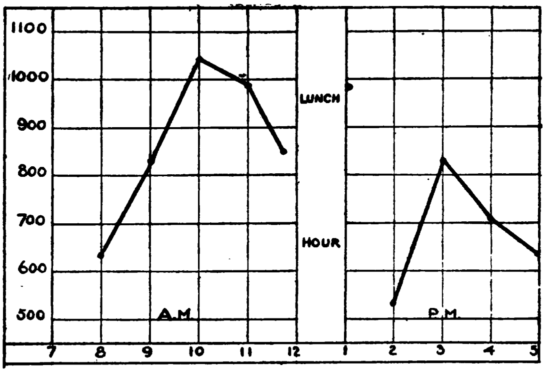
[2] United States Bureau of Mines, Bulletin 69, 1913, Coal-Mine Accidents in the United States and Foreign Countries.

[3] Transactions of the British Association for the Advancement of Science, op. cit., p. 56.

In the curve usually presented accidents are uniformly low in the first hour. They then rise gradually to a peak, most frequently in the penultimate hour of the spell, whence they again gradually decline. In the second spell there is a generally similar rise and fall, often at a somewhat lower level.

CHART 24.—*Distribution of accidents during full working hours.*

MASSACHUSETTS COTTON INDUSTRY, 1913.



Plotted from figures given by the Massachusetts Industrial Accident Board, Report for 1912–1913.

In the following pages we shall attempt to show that the absolute accident figures gain significance for the hourly study of accidents only in relation to the figures of output and of the number of workers present. The figures of absolute accidents furnish at best a rough, and at worst a very misleading, indication of the true object of our inquiry, that is, the accident risk of the workers. That accident rates are also misleading is very effectively shown in the report of the Bureau of Mines already quoted. Whereas in death rates per 1,000 employed the United States heads the list of the various countries studied, in death rates per 1,000,000 tons mined it comes about midway; that is, the hazard of the industry, commonly supposed, on the basis of rates, to be higher in the United States than in any other country, is shown in relation to production to be greater than in four but less than in the other four of eight important countries studied.

THE CURVE OF ACCIDENT RISK.

In the study of industrial accidents and their hourly distribution, it is clear that the point at issue is not the absolute number of accidents in any hour nor the accident rate per number employed, but, given a constant number of workers, the accident risk per unit of output, as suggested in the British Association report of 1915[1], or, in other words, the exact relation of accidents to output.[1] In the present study this exact hourly relation is shown, so far as known for the first time, in the accident-output ratio, termed throughout the report, "accident risk."

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[1] A tentative table, showing hourly correlation of accidents and power consumption in the same factory is given in Use of Factory Statistics in the Investigation of Industrial Fatigue. A Manual for Field Research. Philip Sargant Florence. Columbia University Studies in History, etc. Longmans, Green & Co., New York, 1918, p. 66..

It is evident that the hypothesis put forward by Chaney in 1911 and later abandoned, attributing to fatigue and speed of production as interrelated factors the causation of accidents, has never been tested by sufficiently full and representative statistics of output. From the data of working capacity and output as well as accidents at our command, and the resultant ratio between the two, we are enabled to test this hypothesis more adequately than has hitherto been done and, so far as the findings of the present investigation go, to confirm it.

CONCLUSIONS.

The main conclusions of this study, stated here in brief and later amplified, are as follows: It appears to be established that industrial accidents are due to a complex of causes in which speed of production and fatigue are determining factors.

(*a*) In the absence of fatigue, accidents vary directly with speed of production, owing to increased exposure to risk.

(*b*) The breaking up of this regular variation by fatigue is indicated by—

  (1) The rise of accidents with the fall of output;
  (2) The disproportionate rise of accidents with the rise of output, and the absence of a proportionate fall of accidents with the fall of output in the final hours of the day.

(*c*) The importance of fatigue in the causation of accidents is emphasized by the fact that a higher accident risk accompanies the deeper decline of working capacity—

  (1) In the second spell as compared with the first;
  (2) In muscular work as compared with dexterous and machine work;
  (3) At the 10-hour plant as compared with the 8-hour plant.

(*d*) The level of the accident rate varies inversely with the experience of the workers.

METHODS OF STUDY.

STANDARDS REQUIRED.

A scientific analysis of the incidence of industrial accidents must be based first of all on a correct record and tabulation. It must further correlate accidents with number of workers and rate of output; or in other words give risk per output per worker. Precautions have been taken in the present study to reduce the possibilities of error by satisfying these requirements as nearly as possible.

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[1] See also United States Bureau of Mines, op. cit., p. 89: "In any given coal field or in any two coal fields having identical physical conditions * * * the risk of coal mining would vary almost directly with the average output of coal per day per man."

1. CORRECTNESS OF RECORD.

In order to study the relation of accidents to their possible causes, we must first eliminate errors of record. Such errors are in the main due to inaccurate reporting of the times of injury and incorrect tabulation in respect to hours previously worked by the injured man.

(a) *Accurate reporting.*—Thus, unless special pains are taken either by factory management or investigators to insure a record of the exact time of an accident, the time recorded will naturally be that of the injured man's reporting at the dressing station. But this time may vary, according to the severity of the accident or the carefulness of the worker, from minutes to hours or even days after the actual occurrence of the injury. Records from such reporting, it will be readily apparent, are useless from the point of view of accurate statistics or as a basis for conclusions on the causation of accidents.

In the present study our accident records are based for both plants not on the times of reporting either to the foreman or to the hospital but on the time of the actual occurrence of the injury. The accuracy of these recorded times is checked by the notable promptness of reporting for treatment that prevails at both factories.

At both factories the strength of the safety first movement and its insistence that any injury, however slight, be at once reported for treatment, give legitimate ground for believing that accidents are promptly reported.

The extraordinarily low percentage in cases of sepsis at both plants in recent years further supports the belief that few injuries fail to receive immediate treatment. At the 10-hour plant the proportion of accident cases in which infection had developed before reporting averaged for three years, 1915, 1916, and 1917, only 2.23 per cent of the total number of accidents. At the 8-hour plant the number of cases infected before treatment was even lower, 1.1 per cent of the whole.

For the same years the percentage of accident cases developing infection *after* immediate treatment averaged 0.3 per cent at the 10-hour plant and at the 8-hour factory 0.39 per cent. That the percentage of sepsis following delayed reporting (2.23 and 1.1) is so little in excess of the percentage of infections developing after immediate treatment, in spite of the far greater risk involved in these delayed cases, is an added proof that the amount of late reporting at either factory must be very slight.

Moreover so close a similarity in the figures of infections after immediate treatment at both plants indicates that the general risk of sepsis is about the same at both.

At the 8-hour plant, the convenient distribution of first-aid stations throughout the factory, within easy reach of the various departments, in itself favors promptness of reporting. The hour stated in the tabulation is the time of occurrence either as given by the injured man himself or as recorded by the foreman in his report to the first-aid station. At the 10-hour plant the actual time of injury as well as the time of the report to the foreman is filled in by the foreman on the factory's accident blank, and the tabulation is based on the recorded time of injury. A careful analysis of records made at this factory by the Public Health Service shows the liability of error to be remarkably slight.[1]

(*b*) *Correct tabulation.*—A further source of error lies in charting the absolute number of accidents irrespective of hours previously worked by the injured men. It is plain that no conclusions can properly be drawn as to the relation of accidents to fatigue unless the amount of activity preceding each injury is definitely known and the accidents strictly classified by hours of previous work.

The following precautions were taken by the Public Health Service investigators to secure a correct tabulation on this principle.

At the 8-hour plant, where a complicated system of shifts prevails, careful arrangements were made to have noted in each case of accident the time when the injured employee was scheduled to come to work. Classification of accidents according to the number of hours previously worked was thus made possible. In order to allow for the lunch period, the accidents of the fifth hour during which the lunch interval almost universally occurred were omitted from the tabulation. Accidents occurring in the few departments where the lunch hour fell in the fourth working hour were omitted from the hourly totals throughout the day.

At the 10-hour plant there is no variation in the time of coming to work and the shift works full throughout the day. The lunch interval, 12 to 1, is the same for the entire working force.[2]

No difficulty, therefore, was experienced in making an accurate tabulation of accidents by previous working hours.

Accidents at this plant were classified by hours as follows: 7–7.59, 8–8.59, etc.

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[1] See Note B at end of this chapter: Ten-Hour Plant. I. Reliability of Accident Figures.

[2] Two departments only are exceptions to this rule—hot forge and casting. In these the 3-shift system is in force and both starting time and lunch interval differ accordingly from the hours in the rest of the factory. The total number of accidents occurring in these departments, however, amounted in 1916-17 to only 3 per cent of the total number of accidents in the plant, and though the accident curves showed the characteristic differences due to the shorter shifts, there was no marked concentration of accidents in any one hour. It was clear, therefore, that the influence of these variations on the curve of total accidents was so slight as to be negligible.

2. CORRELATION OF ACCIDENTS WITH NUMBER OF WORKERS.

For a scientific study of the distribution of accidents throughout the working day, there is needed an exact correlation of accidents with the number of workers present from hour to hour. In the absence of such correlation we have no assurance that a rise or fall of accidents may not merely reflect an increase or decrease of the labor force. Such correlation demands that the variations of employment, such as those occasioned by lunch, recesses, lateness, etc., be allowed for. For a study of daily accident rates it would be necessary also that the number of workers be constant from day to day or that days' absences should be allowed for. But the reduction or increase of the force during entire days, as possibly through illness, variations of employment, etc., will obviously not affect the curve of hourly distribution.

The chances of error in our present study lie not in absence but in the changes in the proportion of employment from hour to hour throughout the day. For the lunch period allowance has been made as we have seen on the previous page. Recesses were not in operation at the 10-hour plant during the period of accident study. At the 8-hour plant they affected so small a fraction of the total force as to be negligible.

Lateness remains to be considered, and is the more important because the index numbers in our tables and charts of accidents are all based, as we shall see (pp. 110–115), on the first hour. Should it be proved that exposure to danger is appreciably lessened in this hour by the absence through lateness of any considerable part of the working force, it would obviously not only depress accidents and risk unduly for that first hour, but since this hour is the standard of comparison, unduly raise them for all the other hours as well.

At the 8-hour plant the effect of lateness on the regular number of persons on shift is shown by investigation to be exceedingly slight. The workers after arriving at the factory do not leave the plant until the end of the shift, and early leaving is not permitted, so that no curtailment of actual hours in the factory is possible except by lateness at the beginning of the shift.[1]

According to the official factory record giving total number of employees present and total number of hours worked, the time worked per man, averaged during nine days in February, 1919, was seven and nine-tenths hours. While this record of time worked includes a certain small proportion of overtime, it excludes not only lateness usually due to lack of materials but the legitimate short time of several departments which at night may work only seven hours. Lateness, moreover, of 1 to 15 minutes is recorded as a quarter hour, so that the figures for lateness must greatly overstate its actual amount. It is clear, therefore, that little time is lost at the factory by lateness, since even with the subtractions we have noted the actual time worked is only six minutes short of the full eight-hour schedule.

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[1] Exception may be further made of time lost by accidents, sudden illness, etc. The extreme slightness of the variation in the working force so occasioned, however, can not seriously be held to affect for our purpose the stability of the working force throughout the shift.

To check these figures an investigation was made of the degree of individual lateness in 55 cases occurring in eight departments in January, 1919. The median amount of lateness every day for these sample cases was found to be 10 minutes. The number of men late throughout the factory, however, based on an official count of lateness extending over three months, proved to be only about seven per thousand, or 0.713 per cent of the whole working force of 36,000 men. If we take the sample cases, then, as typical, we may assume that in the whole factory 0.713 per cent of the total force, or 256.68 men, averaged 10 minutes late. This would be equivalent to 42.78 men one hour late (i. e., $\frac{10}{60}$ of 256.68), or 0.12 per cent of the whole working force. By so much, then, employment is reduced and liability to accident lessened in the first hour, but the effect of so minute a fraction in depressing the accident curve during this hour and raising it correspondingly in the others is evidently negligible.

At the 10-hour plant the amount of instability introduced into the working force by lateness, while larger than at the other factory, still constitutes a very small percentage of total employment. The lateness of 4,987 workers at the main plant observed during three to six days, may be fairly assumed to be representative for the total force. The results of this study showed that the average actual lateness in the factory was equivalent to an average lateness of one hour for 74.5 men, or 1.50 per cent of the total working force, or to a lateness for the total force of 1.50 per cent of the first hour. Our correlation of accidents with number of workers is, by this fraction, then, inexact in the first hour; the accident curve here will by so much be unduly depressed, and, since this first hour is the base for the index numbers (see page 103), correspondingly raised in the other hours.[1]

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[1] For the 10-hour plant the figures for lateness are obtained by a somewhat less simple calculation than at the 8-hour plant. Workers arriving late are, for reasons of convenience, grouped according to their degree of lateness as follows: Group A=those arriving before the gate shuts at 7.03; group B=those arriving later than 7.03; group C=the office force, coming on regularly at 8 a. m., and therefore absent but not technically late for the first hour. The numbers of Group C can not be used in the calculation and do not concern us here, as these workers carry only a subnormal accident risk per man as compared with the rest of the factory—0.99 per cent. The accompanying table shows actual lateness at the plant, together with its equivalent in number of men late one hour and in amount of lateness of total working force.

Actual lateness (median).			Men late 1 hour.			Lateness of total force.		
Number.	Per cent of force.	Lateness (minutes).	Number.	Per cent of force.	Lateness (minutes).	Number.	Per cent of force.	Lateness (in per cent of first hour).
A, 262	5.25	1	4.36	0.0875	60	4,987	100	0.0875
B, 78	1.56	16	20.8	.417	60	4,987	100	.417
C, Office force=0.99 per cent of risk	....	60	49.37	.99	60	4,987	100	.99
Total lateness	....	....	74.53	1.4945	60	4,987	100	1.4945

3. CORRELATION OF ACCIDENTS WITH OUTPUT.

But the absolute accident curve, even if based on strictly correct reports and tabulation, and properly corrected for variations in the number of workers, has little significance if unrelated to output. It may be lowered simply by a decline of output, late starting, or early stoppage of work, or other influences unconnected with the true accident hazard. The significant thing, the risk per unit of output, demands correlation of number of accidents with the actual production of the worker and must be expressed by the accident-output ratio.

During much of the day, the curve of this ratio may indeed run fairly parallel to the curve of accidents. The character of the absolute accident curve may at other times be radically misleading. Suppose accidents in the afternoon spell decrease one-eighth, from 120 to 105; suppose further that output decreases one-fourth, from 100 to 75. Absolute accidents, then, have indeed declined, but owing to the still more rapid drop of output, the accident risk per unit of output has risen from 120 to 140 per cent, i. e., $\frac{120}{100}$ to $\frac{105}{75}$. Thus the drop of the absolute accident curve at the end of the spell or shift easily masks its relative rise in comparison with the deeper decline of the output curve. Similarly, the frequently lower afternoon level of the accident curve has led to the assumption that accident risk declines in the afternoon, whereas the relation of the accident to the output curve may show it to be rising.

For the two factories studied in this report the extensive data on production already presented in chapter 2 give unusual opportunity for an exact analysis of the accident risk. These output figures, it should be remembered, are not taken from factory records; they are based on direct count by the investigators present in the factory or by the foreman under their supervision.

It must be recalled, however, that these output figures are corrected for all time lost involuntarily, for repair of machines, failure of power, etc., that is, the rate of work is given as though no interruption had occurred. These corrected figures showing the output rate for hours when actual output fell through no fault of the workers, have given exactness to our conclusions in the chapter on output. In a study of accidents, on the other hand, it might be expected that we should use for exact correlation with accidents the actual output figures. Since lowering the output means as a rule an automatic reduction of accidents it will be clear that a ratio formed by actual accidents over prorated output will unfairly lower the accident risk. In order, however, to avoid introducing here a different though closely resembling set of curves, we shall hold in this chapter to the corrected curves used in the earlier chapters[1] instead of giving the uncorrected figures. It remains for us to consider how far the corrections affect the figures of output and their relation to the accident figures. We are fortunately in a position to prove that the error involved is slighter than may at first appear. In any case it reinforces rather than weakens the argument; in other words, our figures when they diverge from the actual facts understate the accident risk.

Since the corrections for machine repairs and waiting for material occur in the long run with about the same frequency in every hour, these corrections, as they do not alter the distribution of output, do not invalidate the comparison of accident risk per actual unit of output for the different hours, where large groups of operations are involved. At the 10-hour plant, moreover, output in machine work is represented by figures of power consumption which gives actual production, so that no correction has been made for this type of work in which most time is lost for repairs.

Corrections more seriously affecting the output curves have been made at the 10-hour plant for the time lost in starting and stopping work. According to the rule adopted by the investigators no corrections were made for less than three minutes of lost time. At the 8-hour plant workers are so punctual that there were scarcely any corrections. At the 10-hour plant the correction averages 6 per cent of the first hour's output, 5 per cent of the sixth hour's, 8 per cent of the fifth hour's, and 13 per cent of the last hour's. The correction in the first hour, in so far as it concerns lateness, has already been considered. In the three other hours at the 10-hour plant, the actual output is lower and the accident-output ratio should therefore be higher than it is in our tables. In the last hour of each spell the curve of risk is thus respectively 8 per cent and 13 per cent higher than it appears on our chart; in other words, the fatigue indicated by the relative rise of accidents to output is greater than the corrected figures indicate.

In regard then to the possibilities of error involved in reporting, tabulation, and correlation with workers and with output, we have either taken precautions to eliminate them by assuring ourselves of correctness of record, stability in number of workers, and exactness of output figures, or when this was impracticable, have attempted to show with some precision the small amount of possible deviation. We may now proceed to our actual data for the two plants studied.

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[1] The only respect in which the figures of output used in this chapter differ from those presented in the chapter on output is in the inclusion here of figures of morning shifts on three lathe operations studied at the 8-hour plant. These figures were excluded from the output chapter because of the irregularity of the lunch period.

SCOPE OF THE STUDY.

At the 8-hour plant the investigation of the Public Health Service covered all accidents occuring throughout the factory during the three months of September, October, and November, 1917, a total of 13,205. The working force during this time averaged 36,000 and was practically stationary. At the 10-hour plant a study was made of the accident records for two years, 1916 and 1917. For these years the accidents numbered 17,516, and 15,728, respectively, a total of 33,244. This was a time of rising employment due to war orders, the working force mounting, between March, 1915, and December, 1915, from 4,720 to 8,200, in 1916 averaging roughly 11,000, and in 1917, 12,000. The entire study, then, covered roughly 46,000 accidents and 50,000 workers.[1]

A NEW STANDARD OF COMPARISON: THE HOUR OF MINIMUM RISK.

Throughout the earlier part of this report, we have studied the curves of output for each operation or class of operations in relation to the hour of highest efficiency. Our interest has uniformly been in the greater or less approximation of each operation, each type of work, and finally of the factory as a whole to its own best hour of work. To show how much or how little, relatively speaking, the curves of production fell below their highest points, index numbers were adopted as a common measure of hourly output, based for each operation on the hour of maximum output as 100. The index numbers for the several component operations of a group were averaged to give the composite curve of output for the group as a whole; and these group curves were again averaged to obtain a representative curve for the whole factory's activity.

In the study of accidents, on the other hand, it is clear that the best hour is that of the minimum accident risk. This minimum should obviously be the standard of comparison, and the important consideration is how far and for what reasons the accident hazard of other hours rises above it. It is evident from what has preceded that it will not do to take simply the hour of fewest accidents as the minimum; our standard of comparison must be the hour of lowest risk per unit of output, the lowest point of the ratio. On this hour of minimum risk as 100, the index numbers for the curve of accident risk are based.

Our results are expressed in Tables 18 to 22 and charts 25 to 28.

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[1] For tabulation at the 10-hour plant certain accidents were omitted; viz, accidents on the night shift, Saturday and Sunday accidents because of the Saturday half-holiday and the irregularity of Sunday work, accidents during the lunch hour, and for 1916 a certain number of accidents for which no hour of occurrence was specified. The actual number of accidents used as the basis of the tables is accordingly 10,359 for 1916 and 10,205 for 1917, a total of 20,564.

EXPLANATION OF THE TABLES AND CHARTS.

The object of the following tables is, first (Sec. A), to show the exact hourly accident-production ratio or risk per unit of output, together with the method of obtaining it, for each factory and for each individual type of work; and next (Sec. B) to make possible a comparison of the curves of ratio or accident risk, accidents, and output by expressing them in comparable index numbers based on the hour of minimum risk.

The tables of accidents are based on the number of accidents studied at the respective factories according to their incidence by hours worked, and on representative figures showing hourly distribution of output for the factories as wholes. But the maximum and minimum standards found best for the measurement of output and accident variations, respectively, are neither of them proper for comparing the two. We have accordingly used the average as the common standard, and calculated the accident and output figures of each hour as percentages of their respective hourly averages.

Line 1, then, of the tables, section A (see for instance Table 18) gives the variation of accidents from their average hourly number. Beneath are the actual numbers of accidents on which the percentages are based. Line 2 gives the variation of output similarly expressed in terms of its hourly average. But while it was possible to give the absolute accident figures on which line 1 is based, it is manifestly impossible to give the corresponding figures of actual production as the basis for line 2. In the first place it is impracticable in the nature of the case to present actual output figures for each of the multitudinous operations that go to make up the activity of an entire factory. For the purposes of this report the output of the factory as a whole has been represented throughout by the output of certain operations chosen as typical. How the outputs of these concrete operations are combined by the use of the common unit of index numbers to represent the output of the entire factories has been explained on page 107. These index numbers, percentages here of the average hour's output, are given in line 2 of the table for correlation with the variation of accidents. Line 3, then, gives $\frac{\text{line 1}}{\text{line 2}}$ or the ratio of the variation of accidents to the variation of production—that is, the hourly risk per unit of output, which is the special objective of this study.

Line 1 of section B expresses in index numbers the variation of this hourly accident risk from the hour of minimum risk represented by 100. And since for purposes of graphic comparison it is desirable to be able to place in juxtaposition the curve of absolute accidents and the curve of absolute output with the ratio curve which measures their relation, two additional lines of index numbers have been added (2 and 3) representing lines 2 and 1 of A.

DIFFERENCES IN TABLES FOR THE TWO PLANTS.

The three 8-hour shifts at the 8-hour plant enable us to include accidents of all shifts in a single table and chart for the entire factory. At the 10-hour plant accidents are given on the corresponding table and chart for the day shift only, since their incidence in the 12-hour night shift could not be represented in a composite for the plant. Similarly the tables and charts for the several types of work which it has been possible to study separately at this factory include accidents in the 10-hour day shift only.

It will be further noted in the tables of the 10-hour plant that the total number of accidents are given not for the year 1917 alone but for 1916 and 1917. For this line we should logically have taken accidents of 1917 alone to correspond with output figures taken largely from that year. In the interest of absolute fairness, the combination of the two years was chosen, because the 1917 figures show the marked peculiarity of a rise in the last hour of the afternoon. This rise has been verified by an analysis of the figures which proves them reliable.[1]

But in order to avoid the possible imputation of having taken an exceptional curve and thus weighted the evidence, we have combined with the figures of 1917 the figures of 1916, which are thoroughly typical and show the expected drop in the last hour, for the curve here used. This combined curve falls, accordingly, at the end of the afternoon, and hence offers no exception to the conventional accident curve.

For the accident-production ratios, the production figures used in Table 21 for the 8-hour plant are those already given in chapter 2,[2] but are here calculated as percentages of the average instead of the maximum hour. At the 10-hour plant we have adopted a threefold division into types of work as more nearly corresponding to the distribution both of employment and accidents at the factory than the fourfold division adopted in chapter 2 to correspond with the division of the 8-hour plant. In the face, moreover, of certain difficulties in obtaining representative output figures for machine work, we have represented the production of operations of this type by the exact measure of power consumption.[3]

For the production curves at the 10-hour plant, then (Table 22), we have used representative output figures for 1917-18, and power readings for the summer of 1917. To obviate the necessity of allowing for the lighting load, these readings were confined to clear days in the summer months when no artificial lights were needed in the day shift. These power records covered 29 days in June, July, and August, and consisted of readings taken every 15 minutes throughout the day shift. Readings taken at the exact hours of starting and stopping work (7 a. m., 12 m., 1 p. m., and 6 p. m.) were omitted from the hourly averages as not fairly representative.

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[1] Accident figures of 1918 received too late for inclusion in this report show the same tendency to increase in the last hour.

[2] See however p. 106, footnote 1.

[3] For method of obtaining representative figures for the activity of the factory as a whole, and for detailed reasons for the use of the power curve, see Note B, II, at end of chapter.

TABLE 18.—*Ratio of accidents and production in consecutive working hours, ten-hour plant, machine work.*

A. PERCENTAGE VARIATION FROM AVERAGE HOURLY RATE.

	Hours of work.											
	First.	Second.	Third.	Fourth.	Fifth.	Average for spell.	Sixth.	Seventh.	Eighth.	Ninth.	Tenth.	Average for spell.
1. Accidents	71.5	94.4	105.2	112.2	100.4	96.7	84.1	106.2	106.6	110.7	108.7	103.3
Actual number (1916 and 1917, totaled)	346	457	509	543	486	468	407	514	516	536	526	500
2. Production	93.6	102.1	104.7	106.3	101.9	101.7	101.1	101.7	100.7	99.8	88.1	98.3
3. Ratio (accidents/production)	76.4	92.5	100.5	105.6	98.5	94.7	83.2	104.4	105.9	110.9	123.4	105.6

B. INDEX NUMBERS ON BASIS OF MINIMUM HOURLY RATIO (FIRST HOUR).

1. Ratio (accidents/production)	100.0	121.1	131.5	138.2	128.9	123.9	108.9	136.6	138.6	145.1	161.5	138.1
2. Production	100.0	109.1	111.9	113.6	108.9	108.7	108.0	108.7	107.6	106.6	94.1	105.0
3. Accidents	100.0	132.0	147.1	156.9	140.4	135.3	117.6	148.5	149.1	154.8	152.0	144.4

TABLE 19.—*Ratio of accidents and production in consecutive working hours, ten-hour plant, dexterous handwork.*

A. PERCENTAGE VARIATION FROM AVERAGE HOURLY RATE.

	Hours of work.											
	First.	Second.	Third.	Fourth.	Fifth.	Average for spell.	Sixth.	Seventh.	Eighth.	Ninth.	Tenth.	Average for spell.
1. Accidents	72.4	95.2	106.9	120.7	94.5	97.9	80.7	116.6	102.1	100.0	113.8	102.6
Actual number (1916 and 1917, totaled)	105	138	155	175	137	142	117	169	148	145	165	149
2. Production	96.7	106.4	107.6	106.1	99.5	103.3	99.3	101.6	99.1	99.6	84.1	96.7
3. Ratio (accidents/production)	74.9	89.5	99.3	113.8	95.0	94.5	81.3	114.8	103.1	100.4	135.3	107.0

B. INDEX NUMBERS ON BASIS OF MINIMUM HOURLY RATIO (FIRST HOUR).

1. Ratio (accidents/production)	100.0	119.5	132.6	151.9	126.8	126.2	108.5	153.3	137.7	134.0	180.6	142.8
2. Production	100.0	110.0	111.3	109.7	102.9	106.8	102.7	105.1	102.5	103.0	87.0	100.1
3. Accidents	100.0	131.5	147.7	166.7	130.5	135.3	111.5	161.0	141.0	138.1	157.2	141.8

CHART 25.—*Index numbers showing hourly variation of accidents, production, and accident risk.*
TEN-HOUR PLANT—MACHINE WORK.

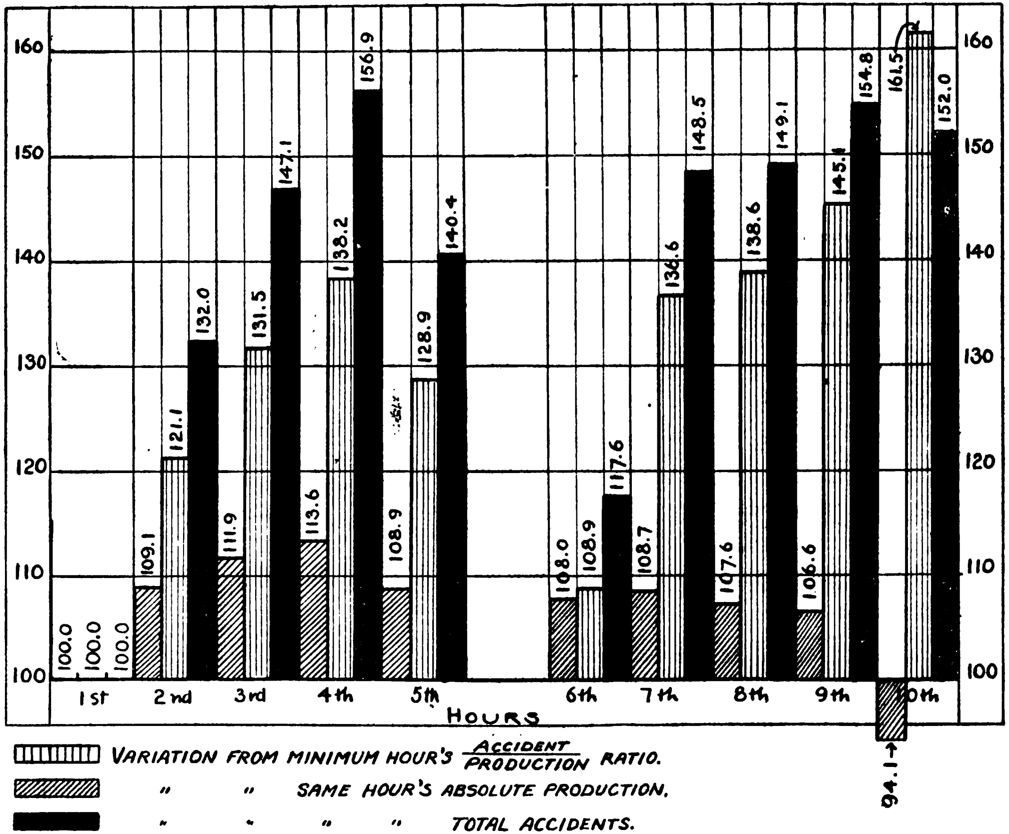


CHART 26.—*Index numbers showing hourly variation of accidents, production, and accident risk.*

TEN-HOUR PLANT—DEXTEROUS HANDWORK.

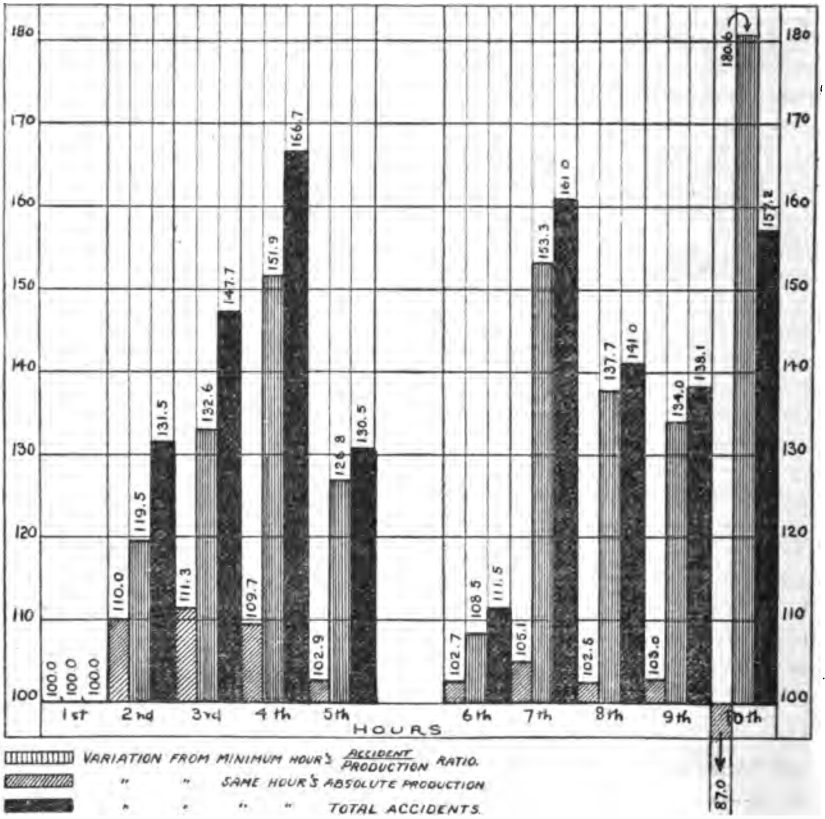


TABLE 20.—*Ratio of accidents and production in consecutive working hours, ten-hour plant, muscular handwork.*

A. PERCENTAGE VARIATION FROM AVERAGE HOURLY RATE.

	Hours of work.											
	First.	Second.	Third.	Fourth.	Fifth.	Average for spell.	Sixth.	Seventh.	Eighth.	Ninth.	Tenth.	Average for spell.
1. Accidents	59.3	91.5	109.1	125.1	95.1	96.0	82.4	102.2	109.4	119.9	105.9	104.0
Actual number (1916 and 1917, totaled)	182	281	335	384	292	295	253	314	336	368	325	319
2. Production	105.2	109.9	107.5	107.3	96.6	105.3	106.4	103.3	98.2	94.7	68.7	94.7
3. Ratio (accidents/production)	56.4	83.3	101.5	116.6	98.5	91.3	76.0	98.9	111.4	126.6	154.1	113.4

B. INDEX NUMBERS ON BASIS OF MINIMUM HOURLY RATIO (FIRST HOUR).

1. Ratio (accidents/production	100.0	147.7	179.9	206.7	174.6	161.8	134.7	175.4	197.5	224.5	273.3	201.1
2. Production	100.0	104.4	102.2	102.0	91.8	100.1	103.0	98.2	93.3	90.0	65.3	90.0
3. Accidents	100.0	154.3	184.0	211.0	160.4	161.9	139.0	172.3	184.5	202.2	178.6	175.3

CHART 27.—*Index numbers showing hourly variation of accidents, production, and accident risk.*

TEN-HOUR PLANT—MUSCULAR HANDWORK.

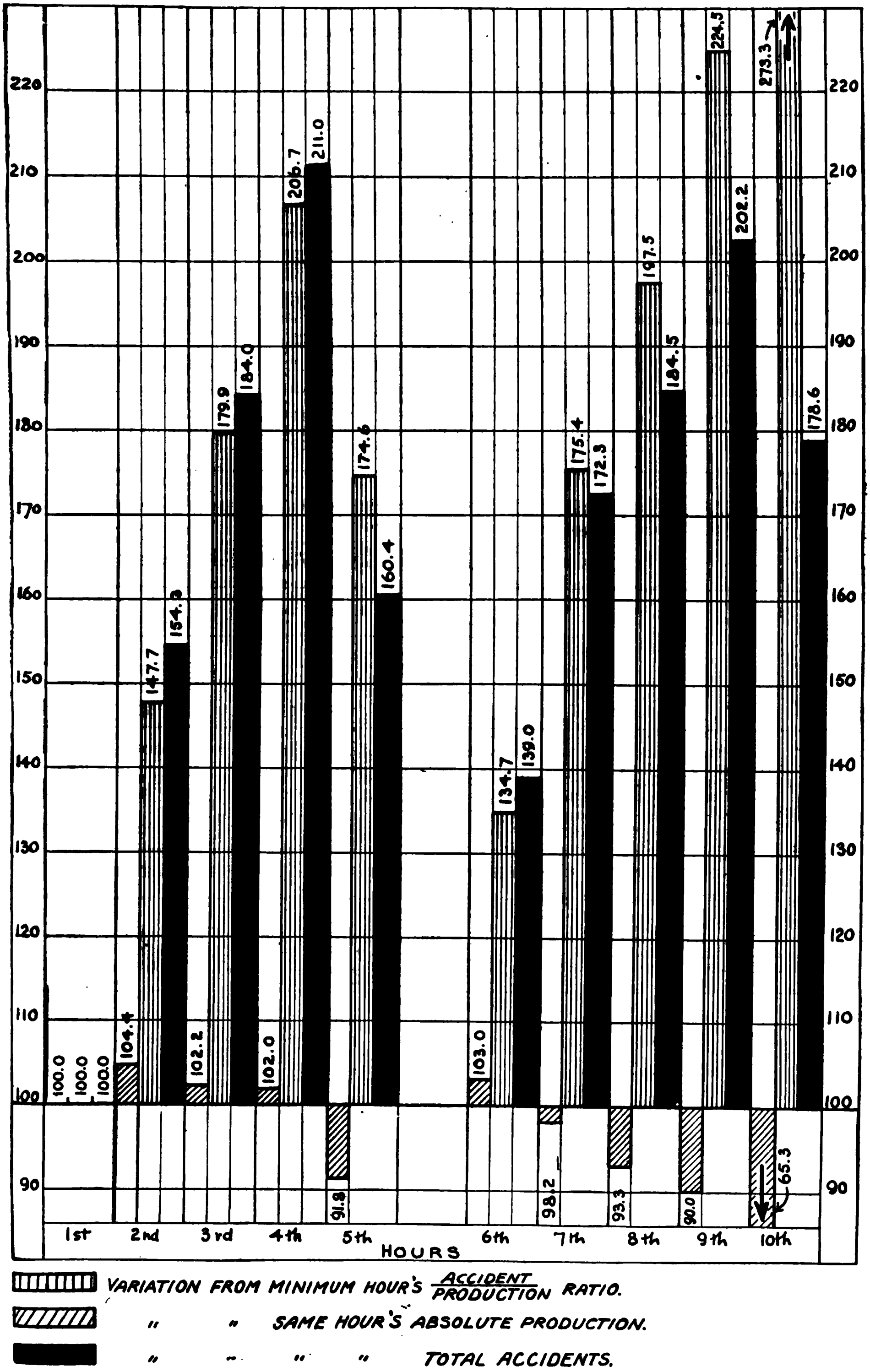


TABLE 21.—*Ratio of accidents and production in consecutive working hours, eight-hour plant, total.*

A. PERCENTAGE VARIATION FROM AVERAGE HOURLY RATE.

	Hours of work.									
	First.	Second.	Third.	Fourth.	Average for spell.	Fifth.	Sixth.	Seventh.	Eighth.	Average for spell.
1. (Accidents)	80.2	105.3	107.9	94.0	96.7	......	107.4	111.7	93.9	104.3
Actual number (3 months, all shifts)	1,505	1,988	2,037	1,774	......	......	2,029	2,109	1,773	......
2. Production	95.5	102.6	103.5	100.5	100.5	......	100.3	100.2	95.3	98.6
3. Ratio (accidents/production)	83.9	102.6	104.2	93.5	96.1	......	107.1	111.5	98.5	105.7

B. INDEX NUMBERS ON BASIS OF MINIMUM HOURLY RATIO (FIRST HOUR).

1. Ratio (accidents/production)	100.0	122.3	124.2	111.4	114.5	......	127.7	132.9	117.4	......
2. Production	100.0	107.4	108.4	105.2	105.3	......	105.0	104.9	99.8	......
3. Accidents	100.0	131.3	134.5	117.2	120.8	......	133.9	139.3	117.1	......

TABLE 22.—*Ratio of accidents and production in consecutive working hours, ten-hour plant, total.*

A. PERCENTAGE VARIATION FROM AVERAGE HOURLY RATE.

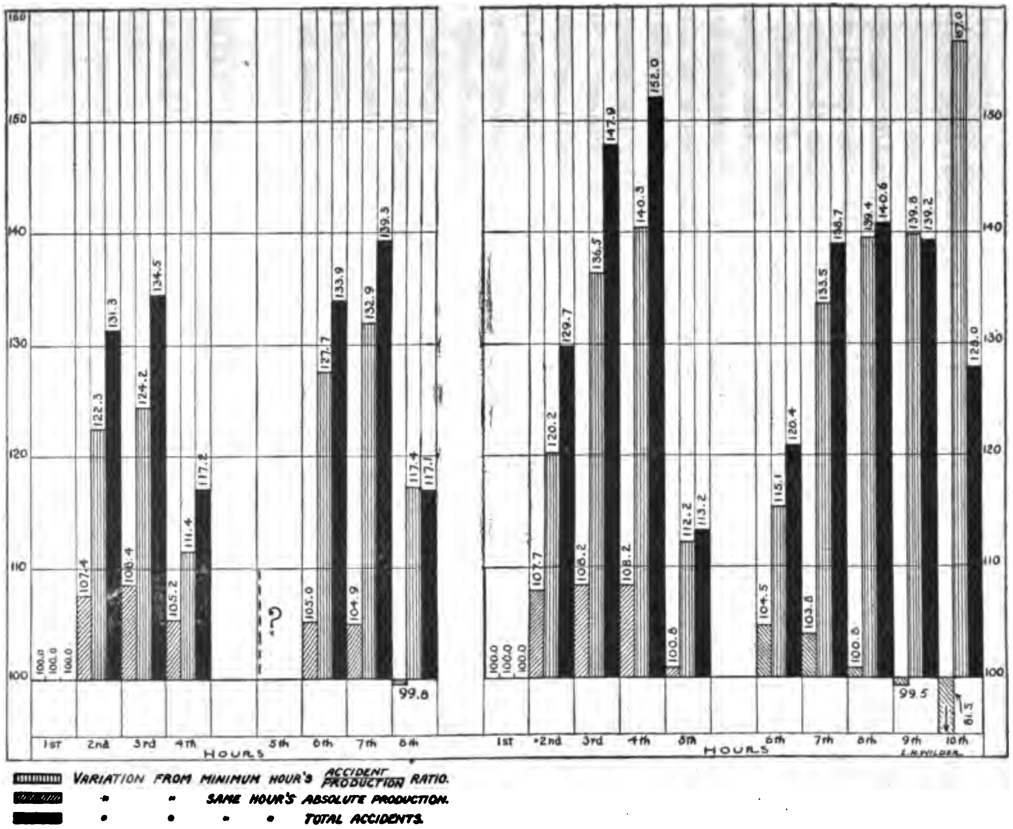
	Hours of work.											
	First.	Second.	Third.	Fourth.	Fifth.	Average for spell.	Sixth.	Seventh.	Eighth.	Ninth.	Tenth.	Average for spell.
1. Accidents	76.4	99.0	112.9	116.1	86.5	98.2	91.9	105.9	107.4	106.3	97.8	101.8
Actual number (1916 and 1917, averaged)	785	1,018	1,161	1,193	889	1,009	945	1,089	1,104	1,093	1,005	1,047
2. Production	98.5	106.1	106.6	106.6	99.3	103.4	102.9	102.2	99.3	98.0	80.3	96.6
3. Ratio (accidents/production)	77.6	93.3	105.9	108.9	87.1	95.0	89.3	103.6	108.2	108.5	121.8	105.4

B. INDEX NUMBERS ON BASIS OF MINIMUM HOURLY RATIO (FIRST HOUR).

1. Ratio (accidents/production)	100.0	120.2	136.5	140.3	112.2	122.4	115.1	133.5	139.4	139.8	157.0	135.8
2. Production	100.0	107.7	108 2	108.2	100.8	105.0	104.5	103.8	100.8	99.5	81.5	98.0
3. Accidents	100.0	129.7	147.9	152.0	113.2	128.6	120.4	138.7	140.6	139.2	128.0	133.4

CHART 28.—*Index numbers showing hourly variation of accidents, production, and accident risk.*

EIGHT-HOUR PLANT. TEN-HOUR PLANT.



NOTE.—Lunch period at Eight-Hour Plant=30 minutes; at Ten-Hour Plant=1 hour.

CAUSATION OF ACCIDENTS: CONCLUSIONS AMPLIFIED.

A careful study of the tables and charts results in the following conclusions, already given in brief, on the causation of industrial accidents.

The accident curve is the result of two main interacting influences: speed of production and fatigue.

1. APPROXIMATION OF THE CURVES OF ACCIDENTS AND OUTPUT: SPEED OF PRODUCTION.

In the absence of fatigue, accidents vary in the main with speed of production. They may vary at the same rate with speed, when the curves will be parallel, or at a more rapid rate when the curve of accidents will be of the same general form as that of output, but steeper. This variation is roughly illustrated in certain types of work by the rise of accidents with rising output in the earlier hours of the day. During these hours the increase of injuries is to a considerable extent automatically determined by the added number of motions with the attendant exposure to danger, or by the generally increased risk inherent in more highly speeded machinery. Similarly, with lowered speed, the automatic reduction of motions and attendant danger will lower accidents at the end of each spell and preserve the correspondence of the curves. Exact variation of accidents with output, though at a more rapid rate, is most closely approximated in both spells at the 8-hour plant, where fatigue is only slightly indicated, and at the 10-hour plant in the first four hours of machine work,[1] the type of activity showing least evidence of fatigue. In both cases the variation of accidents with output is roughly as 4 to 1, or in other words, accidents vary four times as fast as output.

2. DIVERGENCE OF THE CURVES OF ACCIDENTS AND OUTPUT: FATIGUE.

(*a*) *Disproportionate rise.*—That the variation of accidents with the increase or decrease of output is not a mere mechanical result of varying speed is shown by the fact that the rate of variation is not constant. Both in dexterous work and to a less degree in machine work at the 10-hour plant the rise of accidents is disproportionate to the rise of output. Other factors besides speed of production must account for this increase. Among these, loss of coordination, the readjustment of rhythm to changing speeds, may play some part. Prominent among these factors appears to be fatigue, to which the accident curve, it has been suggested, responds more sensitively and more quickly than the curve of output. According to this hypothesis, fatigue is registered first not in a lessened quantity of work but in impaired quality, in errors and growing inaccuracy. In chapter 2 we have traced the decline of working capacity in regard to quantity of output only. Our present data tend to show that, even while output is still rising, the onset of fatigue may be indicated by a disproportionately great increase of accidents.[1]

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[1] In this chapter machine work includes miscellaneous and lathe machine work. See Note B, II at end of the chapter.

(*b*) *Striking disparity of the curves of accidents and output.*—In all hours of falling output except the final hours of the spells [2] accidents continue to rise with the fall of output. Even at the 8-hour plant, where, as we have seen, the variation of accidents with output is in most hours approximately exact, a fractional decline of output from the sixth to the seventh hour is accompanied by a six-point rise of accidents. In this striking disparity the influence of fatigue in the causation of accidents is seen in conspicuous contrast to that of speed of production.

(*c*) *Disproportionate fall of the curves of accidents and output.*—In the final hours of the day accidents fall with the deeper fall of output. In the absence of fatigue, this decline of accidents should be, as we have seen, proportionate to the decline of output, owing to lessened exposure. But the counter-influence of fatigue breaks up this correspondence. By tending to increase accidents it checks their automatic decline. So much greater, therefore, is the fall of output than the fall of accidents that accident risk still ascends. (See ninth and tenth hours of the 10-hour composite, chart 28, p. 115).

ANALYSIS OF SEPARATE TYPES OF WORK.

We may now proceed to test our conclusions in detail by the tables and charts. At the 10-hour plant it has been possible to make a detailed analysis of sample accident figures for each of the three types of work, machine, dexterous, and muscular, each of which has been taken roughly to represent a third of the activity and a third of the accidents in the factory as a whole, as explained in detail in the Note on the Method of Obtaining Representative Production Figures for the Ten-Hour Plant as a Whole at the end of this chapter (p. 136).

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[1] The hypothesis that incipient fatigue is the true explanation of this irregularity is supported by certain experiments made by Franz, Woodworth, and others on the relation of speed to inaccuracy. While these experiments were carried on for short periods of time and not, like industrial processes, during entire days, yet the analogy between them and the relation of accidents to production is close and suggestive.

"It has sometimes been hastily assumed," says Franz, "that the effects of fatigue are always to be noted in a reduction in the amount of mechanical work as measured in foot-pounds or kilogram-meters, or in the number of movements or operations which can be performed in a certain amount of time. There is, however, another factor which in certain types of occupations is much more important than the quantity of work or its force. This is the accuracy of the operation."

"Fatigue," Franz finds, "is evidenced by inaccuracies in movement, and we have facts which indicate that the accuracy decreases as the speed is increased, although not in direct proportion (Woodworth)." * * *

The experiments made by Franz in the laboratory were comparable in their requirements to those of a simple mechanical operation. The subject was required to hit with a pencil certain designated points on a target at differing rates of speed. The results indicated that "the inaccuracies at the slowest speed are insignificant, those at the middle speed are many times greater, and those at the high speed are more than proportionally greater than those of the medium speed".

Transactions of the Fifteenth International Congress on Hygiene and Demography. 1912. Vol. III, p. 512. Fatigue Factors in Certain Types of Occupations. Shepherd Ivory Franz.

See also, Psychological Review Monograph V, 1899, Supplement No. 13. The Accuracy of Voluntary Movement. Woodworth.

[2] An exception to the rule must be noted in the eighth hour of the erratic curve of dexterous handwork at the 10-hour plant.

MACHINE WORK.

Machine work, it will be remembered, shows at both plants a steadier maintenance of output than any other type of work. In many operations the level of production is to a greater or less degree mechanically determined and maintained; in others, fatigue, as we shall see in a subsequent chapter, appears to be reduced or masked by rhythm. Since in the absence of fatigue accidents vary roughly with speed of production and since fatigue is the chief cause of disparity in the two curves, it is natural to expect that in the type of work showing least evidence of fatigue in its output record, divergences will be comparatively slight. This is in fact the case, the chart for machine work[1] (chart 25, p. 111) showing flatter curves with a nearer approach to parallelism than those for either dexterous or muscular work.

The first four hours of machine work thus offer an almost exact illustration of the variation of accidents with speed of production. The relation of variations in accidents to variations in output, as has been remarked, is very nearly 4 to 1. There is a close similarity between the three curves shown on the chart though the rise of accidents and risk is much steeper than that of output.[2] The recuperation of the lunch interval pulls down accidents in the first hour of the afternoon, but the rapid onset of fatigue is shown by the disproportionately steeper rise of accidents in the second hour.

The striking divergence of the curves sets in with the fall of working capacity in the third hour of the second spell. Accidents and risk continue to rise slowly and steadily till the fourth hour. In the last hour accidents slightly decline, but so much greater is the fall of output that the rise of the ratio is very marked, amounting to 16 points.

DEXTEROUS WORK.

Much greater disparity of the accident and output curves is shown in the first spell of dexterous work (chart 26). In proportion as fatigue is more marked in this type of work, its causal relation to risk should be more clearly apparent. Production reaches its peak in the third morning hour, accidents rising with it, but the impairment of working capacity is registered as early as the third hour in the marked disproportion of the rise of accidents. In the fourth hour this impairment is shown both in falling output and a continued rise of accidents. In the last hour of the spell there is a mechanical decline of both absolute accidents and risk with the continued fall of output. Further explanation of this phenomenon is needed; it is possible that with the anticipation of the noon rest a recovery of alertness and attention lowers both accidents and risk.

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[1] In all the accident charts, the reader must bear in mind that the columns of accidents and risk must be measured like the output column from the base line 100. It will be evident that if accidents varied with output in the relation of 1 : 1, the ratio would remain 100 and the curve of risk would accordingly not appear on the chart.

[2] For a discussion of the fifth hour of the morning, see Note A at the end of this chapter.

In the afternoon the very irregular output curve is roughly paralleled in the first 3 hours by the curves of accidents and risk. The fourth hour of the second spell is an exception to all rules so far laid down; the only case in the charts where rising output is accompanied by a fall both of accidents and risk. It would seem probable that the spurt of energy registered in output lowers here both actual number and risk of accidents. But the abrupt failure of working capacity in the last hour is indicated by the drop of output, the marked rise of accidents, and the steeper rise of risk.

MUSCULAR WORK.

If our statement of the rôle of fatigue in the causation of accidents has been correct, its correctness should be demonstrable in the type of work most subject of the three to fatigue. Muscular work should afford our most striking illustration of the disparity of the output and accident curves, the widely different variations in accidents as compared with output, and the mounting of risk with the fall of working capacity. In this type of work, it will be remembered, (see chap. 2, pp. 44, 50) the fall of output sets in after the second, or even after the first hour, and the decline continues steadily till the end of the spell, the last hour dropping far below the first. In the first hour of the afternoon there is a marked recovery of speed, due to the recuperation of the lunch interval; from this point, however, output sinks rapidly to the abrupt downward plunge of the last hour. In contrast to these declining curves of production, the accident curve rises by abrupt increases to a maximum in the fourth hour of each spell, followed by the normal drop in the fifth. This is a curve of conventional form (see chart 27), but of exaggerated height, the index numbers rising in the fourth hour to 211 in the morning and 202.2 in the afternoon, respectively. In the second spell accidents rise as output declines until the last hour, when a comparatively slight fall in accidents (23.6 points) is accompanied by the phenomenal rise of the ratio by almost 50 points, to the index number of 273.3 in the last hour.

HEAVIER ACCIDENT RISK OF SECOND SPELL.

The disparity of the accident and output curves may be further traced by comparing the hourly averages of accidents and output for the first and second spells (Table 23). In each type of work the second spell shows a fall of output coincident with a rise of accidents and a still more marked rise of risk. Higher risk accompanies in each case the heavier fatigue of the second spell. This excess risk, expressed as a percentage of the average of the first spell, is, as we should expect, least in machine work (11.5), slightly greater in dexterous work (13.2), and more than doubled in muscular work (24.3).

TABLE 23.—*Comparative accident risk of first and second spells: Separate types of work.*

	Accidents.	Production.	Ratio.
Machine work:			
Average first spell	135.3	108.7	123.9
Average second spell	144.4	105.0	138.1
Percentage difference	6.7	−3.4	11.5
Dexterous work:			
Average first spell	135.3	106.8	126.2
Average second spell	141.8	100.1	142.8
Percentage difference	4.8	−6.3	13.2
Muscular work:			
Average first spell	161.9	100.1	161.8
Average second spell	175.3	90.0	201.1
Percentage difference	8.3	−10.1	24.3

The increase of accident risk in the afternoon is even more striking, if, instead of the averages given above, we compare the two spells hour by hour (Table 24).

TABLE 24.—*Comparative hourly accident risk of the two spells: Separate types of work.*

	Hours.				
	1	2	3	4	5
Machine work:					
First spell	100.0	121.1	131.5	138.2	128.9
Second spell	108.9	136.6	138.6	145.1	161.5
Percentage difference	8.9	12.8	5.4	5.0	25.3
Dexterous work:					
First spell	100.0	119.5	132.6	151.9	126.8
Second spell	108.5	153.3	137.7	134.0	180.6
Percentage difference	8.5	28.3	3.9	−11.8	42.4
Muscular work:					
First spell	100.0	147.7	179.9	206.7	174.6
Second spell	134.7	175.4	197.5	224.5	273.3
Percentage difference	34.7	18.8	9.8	8.6	56.5

HEAVIER RISK OF MUSCULAR TYPE OF WORK.

In this comparison, muscular work again shows its greater hourly risk. Hour for hour, even in machine work, with its remarkable maintenance of working capacity, the second spell carries a heavier risk than the first, the excess risk in the tenth hour being double that of any other afternoon hour. In the tenth hour of dexterous work, the excess risk is more than 50 per cent greater. The erratic output curve produces in this type a curious decrease of risk in the ninth hour, which can not, however, mask the general rise. But the rise of risk in the other types of work is unimpressive compared with the strikingly increased hazard of the second spell of muscular work. Hour by hour in this second spell, the deeper fall of the output rate is emphasized by the upward rise of the curve of risk. The extraordinary last hour's peak, doubling the risk of the first hour of the afternoon and almost tripling that of the first morning hour, marks by its height the menace of fatigue to safety.

THE COMPOSITE CURVES.

The foregoing charts have shown as accurately as possible the relations of the curves of accidents, output, and risk in individual types of work at the 10-hour plant. It must be carefully noted, however, that neither table nor chart for any separate type of work represents all the accidents included under this type in the whole investigation. The individual charts must be regarded as samples of their respective types, valuable indeed and significant, but having no exact correspondence each with a third of the total accidents studied. Thus, while the tabulation covers some 20,564 accidents at the 10-hour plant and the proper quota for each type for the two years would therefore be 6,855, the chart for dexterous work represents only 1,454, that for muscular work 3,070, and that for machine work 4,840, these figures representing all cases of accident assignable to separate types of work.

The composite curves on the other hand (chart 28 and Tables 21 and 22) represent all accidents studied[1] at the respective factories within the period of investigation. As a picture of the factories, these curves have both the interest and the defects of an average· They obscure on the one hand all the individual differences and distinction of the separate types of work, their characteristic divergences thus often neutralizing each other. Yet they give us, as no individual curves can do, a synthetic representation for each plant of the relation of accidents to production at any given hour. Though flatter than the individual curves and therefore less emphatic in their testimony at special points, they afford strong general corroboration of the truth of the particular findings for the separate types of work. They offer, moreover, the opportunity of contrasting the two general systems of production in operation at the 8- and the 10-hour plants which the group curves afford for separate types of work.[1]

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[1] With exception at 10-hour plant as noted, p. 107.

TEN-HOUR PLANT: COMPOSITE CURVE.

The composite chart for the 10-hour plant (chart 28) presents a typical picture of the curves resulting from the main factors in accident causation. The rise of output for the first three hours of the morning, the sharply disproportionate rise of accidents, the checking of the rise of output in the fourth hour, and the continued rise of accidents all typify the interaction of speed of production and fatigue in the distribution of accidents. In the last hour of the first spell alone accidents fall with the fall of output and risk also declines.[2]

The level of output in the third and fourth hours furnishes a good illustration of the canceling of individual differences in a composite curve. Reference to the sample charts for this hour shows that while the total production of the factory is equal to that of the previous hour, this equality disguises marked disparities in the separate types of work. Thus in both muscular and dexterous work, according to the indication of the sample charts, output declines in the fourth hour; in machine work alone it rises just enough to neutralize the decline in the composite.

In the second spell at the 10-hour plant the divergence of the accident and production curves is much greater and the divergence of the accident and risk curves is at its height. Here, as against the almost level output of the middle hours of the spell at the 8-hour plant and its decline of five points in the last hour, output falls steadily throughout the spell, and in the last hour plunges 18 points below the level of the previous hour. Accidents in the meantime rise till the third hour and then sink, carried downward by the ever-increasing fall of output. But so much deeper is the fall of output than that of accidents that with the fourth hour the curve of risk rises while accidents fall, and in the last hour mounts to its peak for the day.

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[1] Group differences and extremes are to some extent canceled in the composite charts. This accounts in part for the steeper rise and fall of the separate curves and the more pronounced illustration they furnish of the determining factors of accident risk.

These extremes in the group curves are due in part to the fact that the index numbers are based not on the average, which would reduce the possibility of fluctuation, but on a single hour, that of the minimum risk. From this procedure it follows that an especially high accident immunity in this single hour which forms the basis of comparison may result in an extraordinary rise by contrast of the other hours. This is in fact the case in muscular work, where working capacity and accident immunity are proportionately higher in the first hour than in any other type (chart 27). From this cause alone it is natural that the muscular curve should be very much higher than the composite curve which is lowered by the influence of the other types of work.

Examination of the figures for these other types makes it clear, however, that even in the case of dexterous and machine work, where there is no marked peculiarity of an initial low hour, the subordinate curves run well above the level of the composite curve. We must conclude that in the samples of accidents studied there is a difference in distribution, as compared with the distribution of total accidents, which emphasizes the height of the curves; the number of accidents in the first hour of the separate curves is proportionately less than in the composite. It is natural, therefore, that the composite curve is flatter than the curves for the subordinate types.

[2] For discussion of the last hour of the morning spell, see Note A at the end of this chapter.

EIGHT-HOUR PLANT: COMPOSITE CURVE.

Since, as we have seen, the outstanding feature of production at the 8-hour plant is its steady maintenance and comparatively slight fall, we should expect in this chart (chart 28) as in that of machine work some approach to parallelism in the curves of accidents and output. This is notably the case in the first spell of the 8-hour plant composite curve. Accidents and risk rise and fall with output, though much more steeply.

The omission of the fifth hour's accidents on account of the uncertain incidence of the lunch period leaves curves of only three hours in the second spell to compare with output. These curves of accidents and risk are more nearly level than those for the second spell on any other chart, but, as we have seen, the rough parallelism of the first spell is lost.

It is notable that even at this plant, where fatigue is least registered in the curve of output, accidents and accident risk continue to rise, while output is falling between the sixth and seventh hours. The recovery in the eighth hour where both accidents and risk decline with falling output may indicate the anticipation of rest and change. At this plant, it should be remembered, over two-thirds of the total force finishes the day's work between 2 and 3 o'clock in the afternoon, so that part of the day is still available outside of the factory. Yet so marked a fall of risk in the last hour of the day obviously raises speculation and needs further study.

HEAVIER ACCIDENT RISK OF SECOND SPELL: THE TWO FACTORIES.

The coincidence of higher accident risk with the heavier fatigue of the second spell which we have already observed in the charts and tables for separate types of work, is borne out by the spell averages for the entire factories, respectively (Table 25).

Here, as in all other tables and charts in this chapter, it is necessary to omit the accidents of the fifth hour at the 8-hour plant, owing to the varying length of the lunch interval. In order to insure as fair a comparison as possible between the morning and afternoon spells, we have omitted in the following table the accidents, output, and ratio of the first hour of the morning spell at this factory, as well as of the first hour of the afternoon spell.

TABLE 25.—*Comparative accident risk of first and second spells: Entire factories.*

	Accidents.	Production.	Ratio.
Eight-hour plant:			
Average first spell (first hour omitted)	127.7	107.0	119.3
Average second spell (first hour omitted)	130.1	103.2	126.0
Percentage difference	1.9	−3.6	5.6
Ten-hour plant:			
Average first spell	128.6	105.0	122.4
Average second spell	133.4	98.0	135.8
Percentage difference	3.7	−6.7	10.95

At the 8-hour plant the index numbers show the risk per unit of output to be 5.6 per cent higher in the second spell than in the first; at the 10-hour plant nearly 11 per cent higher. The corresponding fall of output is 3.6 per cent at the first factory as against 6.7 per cent at the second.

By comparing further the corresponding hours of the two spells, as we did in the case of the individual charts, it will be seen that the second spell carries hour for hour a decidedly higher risk than the first, the seventh hour showing the most unfavorable ratio.

TABLE 26.—*Comparative hourly accident risk of the two spells: Eight-hour plant.*

	Hours.			
	1	2	3	4
First spell	100.0	122.3	124.2	111.4
Second spell	(?)	127.7	132.9	117.4
Percentage difference	....	4.4	7.0	5.4

The increased hazard of the second spell is much more striking at the 10-hour plant. Here, as no hour is omitted, our comparison of risk may be exact throughout the day.

TABLE 27.—*Comparative hourly accident risk of the two spells: Ten-hour plant.*

	Hours.				
	1	2	3	4	5
First spell	100.0	120.2	136.5	140.3	112.2
Second spell	115.1	133.5	139.4	139.8	157.0
Percentage difference	15.1	11.1	2.1	−.36	39.9

It is noteworthy that the rising risk for the factory as a whole is checked in the fourth afternoon hour by the fall of output which carries absolute accidents down with it; here decreasing speed and rising fatigue seem for an hour or more nearly to neutralize each other. (See chart 28.) But the sharp rise of the last hour's risk, matching the deep drop of output, as well as the heavier risk of the afternoon spell as a whole, is a strong reinforcement of the argument for the rôle of fatigue in accident causation.

HEAVIER RISK AT THE TEN-HOUR PLANT: THE TWO FACTORIES.

We have seen that the excess risk of the second spell is greater at the 10-hour plant than at the other factory, corresponding to its deeper decline in working capacity. Comparing now actual hourly risk throughout the day at the two plants, we see the highest hour's risk at the 8-hour plant to be 124.2 in the first spell, and 132.9 in the second. At the 10-hour plant, on the other hand, the peak of risk in the first spell is 140.3 and in the second 157. For 6 hours out of 10, moreover, the 10-hour plant carries a risk higher than the highest hour's risk at the 8-hour plant. This higher risk is due to greater disproportion of accident increase in the first spell as well as greater decline of working capacity in the second. In general, then, the plant exhibiting the indications of heavier fatigue in output is also the plant subject to the higher accident risk.

NIGHT SHIFT: THE TEN-HOUR PLANT.

On the night shift at the 10-hour plant the numbers of workers employed and accidents occurring are too small to yield conclusive data. Interpretation of the figures is complicated, moreover, by the irregular presence of overtime day-shift workers during the first three hours of the night shift. No means were afforded by the factory records of separating overtime accidents from those involving the night workers alone, and the resultant figures, representing the accident liability of men at wholly different stages of the curve of work, make any intelligent analysis for these hours impossible.

ACCIDENTS AND POWER CONSUMPTION.

A further indication of the relation of fatigue to accidents is afforded by charts 29 and 30, representing the distribution of accidents and power at each plant by hours of the day throughout the 24 hours.[1] These curves have admittedly only a rough correspondence, since power can serve as a measure of output only for machine work, which constitutes about one-half of the activity of the 8-hour plant and only one-fourth of that of the 10-hour plant, while the accident curves are based on all accidents occurring at the respective factories. They may fairly, however, be held to indicate certain general tendencies in the relation of accidents and output.

These curves of accidents and production by "clock" hours are naturally of wholly different character from the curves of each by working hours. In contrast to the curves previously given, no more significant comment than these charts could be offered on the studies which attempt to base conclusions on the absolute accident curve. Accident and power curves are undoubtedly influenced by the speed of production, but the dominant factor influencing the shape of these curves is the number of men at work. Thus the high points of both curves are naturally reached when the shifts are working full and the low points when large numbers of men are taking meal intervals (see 11 a. m.–12 m., 7–8 p. m., at the 8-hour plant), or where toward the end of a shift men begin to knock off work (see 6–6.40 a. m. at the 10-hour plant), or where (9 p. m. at the 10-hour plant again) overtime ends in the evening.

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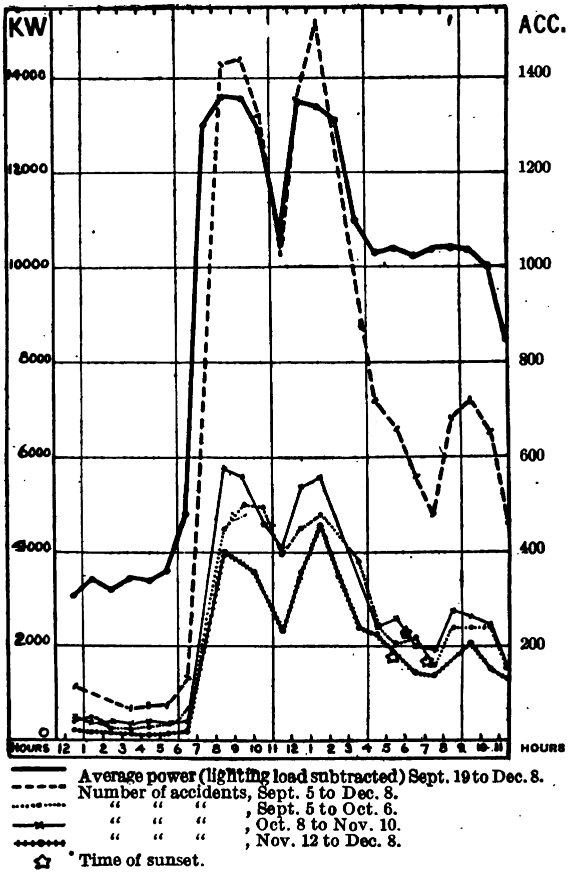
[1] Power consumption readings were taken every quarter hour to form the average for any single hour. Thus for the average of the hour 8 to 9 a. m. the readings 8, 8.15, 8.30, and 8.45 a. m. are used. The 9 o'clock reading is included in the hour 9 to 10. This corresponds with the hourly tabulation of accidents in which the 9 o'clock accidents are included in the hour 9 to 10 a. m., not 8 to 9 a. m., etc.

At the 8-hour plant there are but 4 hours in the 24 when the shifts are definitely known to be working full. These are 8 to 10 a. m. and 1 to 2 p. m. for the morning shift, and 9 to 10 p. m. for the evening shift. In these hours the peak of the accident curve shows a definite tendency to follow the peak of the power curve by one hour. In other words, accidents rising with power continue to rise for an hour after power has reached its maximum and is either stationary or declining. This would suggest that accidents are the result of fatigue due to the previous intensity of work.

CHART 29.—*Curves of accidents and power load in consecutive hours of the day.*[1]

EIGHT-HOUR PLANT.



At the 10-hour plant, except for such lateness as may exist (see p. 104) and except for the general lunch hour from 12 to 1, the day shift works full throughout the day. The morning peak of power is reached at 8.30 a. m. and is followed by a marked decline; the peak of accidents at 9.30 a. m. In the afternoon, power is lower and accidents almost equally high. The accident peak for the spell coincides with the first power peak for the spell at 2.30 p. m.; then accidents decrease until 4.30 p. m., while power again rises owing to the inclusion of power for lighting on cloudy days, which could not be eliminated from the record in the year 1916.

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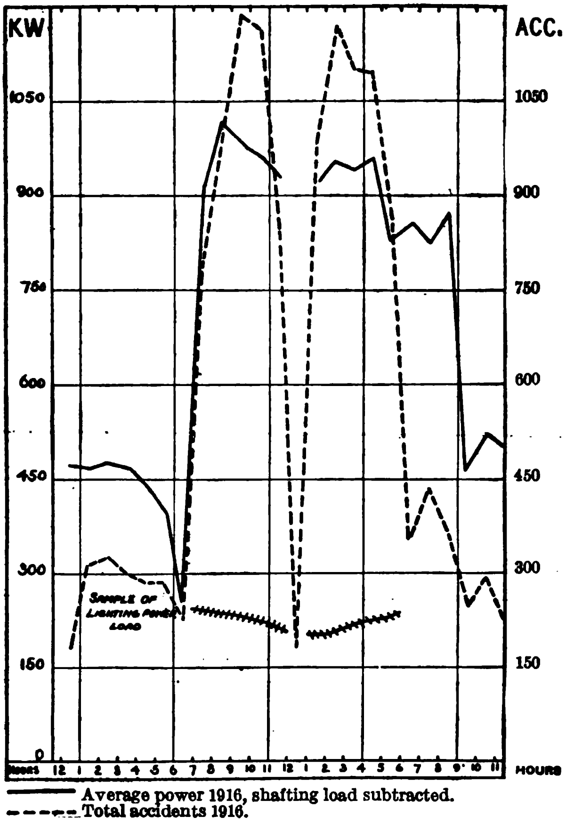
[1] Kilowatts are indicated by the scale at the left, accidents by the scale at the right.

CHART 30.—*Curves of accidents and power load in consecutive hours of the day.*[1]

TEN-HOUR PLANT.



ACCIDENTS AND INEXPERIENCE.

THE HIGH RISK OF BEGINNERS.

It is generally recognized that inexperience is one of the most important elements in the causation of industrial accidents. What has not been sufficiently realized is the close parallelism of the rates of accidents and of inexperience. The industrial risks of beginners have been shown to be high. Interesting testimony on this subject is given in the iron and steel report already quoted. A table giving the incidence of accidents to press hands beginning work on the machine shows that on the first day of employment more than 5 times as many were injured as during all the rest of the first week; 26 times as many, as from the second week to the end of the first month; 100 times as many, as from the second through the sixth month, etc. Another table covering longer periods of employment shows the accident frequency rates per 1,000 workers at a steel plant falling from the exceedingly high rate of 111.3 per 1,000 in the first six months through increasing lengths of service to 19.7 for from 5 to 10 years and to zero after 15 years.[1]

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[1] Kilowatts are indicated by the scale at the left, accidents by the scale at the right.

Similar testimony based on a sample of 600 persons especially questioned is offered by the accompanying chart (p. 129), showing the proportion of workers injured by accident at the 10-hour plant, according to their length of continuous employment. To find the comparative accident rate of beginners we must relate this chart, however, to the chart showing different lengths of employment of the total labor force given in the chapter on turnover (p. 169).

The following table, while far less striking than the figures quoted above, confirms the higher risk of beginners and shows the accident rate to be highest in the first three months of employment, lower during the rest of the year, and decidedly lower after a year's employment.

TABLE 28.

	Per cent distribution of accidents according to length of employment of injured persons.	Per cent distribution of working force according to length of employment.	Comparative accident liability according to length of employment.
First 3 months	34.7	28.0	1.24
Remainder of year	21.4	19.0	1.13
Over 1 year	43.9	53.0	.83

VARIATION OF ACCIDENTS AND INEXPERIENCE AT TEN-HOUR PLANT.

In the four largest departments of the 10-hour plant the Public Health Service made a special study of the relation of accidents to inexperience during seven months of 1916–17. The curves expressing the results of this study (chart 32) show a striking degree of parallelism between the two, the accident rate rising with the increase in the proportion of men newly hired during the month and decreasing when the labor force continues stable. These curves, it should be noted moreover, are based on a period of comparatively stable employment. Had a year of sharply rising employment like 1915 been chosen for the study, the joint rise of the peaks of inexperience and accidents would doubtless have been even much more striking. The tendency of the accident curve to follow the curve of inexperience is less strikingly but no less unmistakably shown in the charts given by the iron and steel report of 1918, showing the relation of labor recruiting, employment, and output to accident occurrence, 1908 to 1914.[1]

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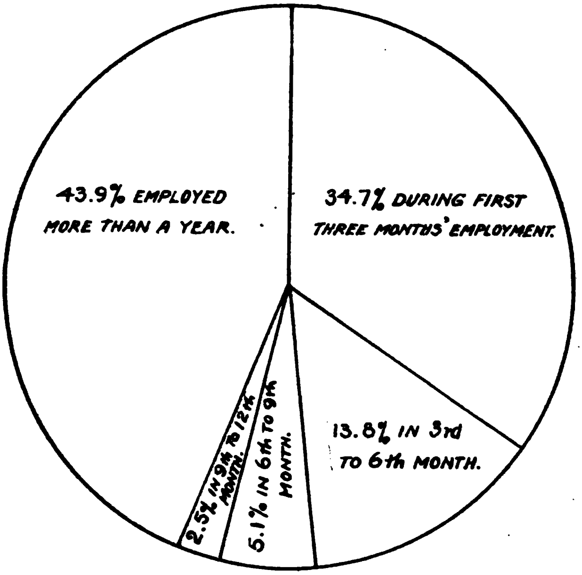
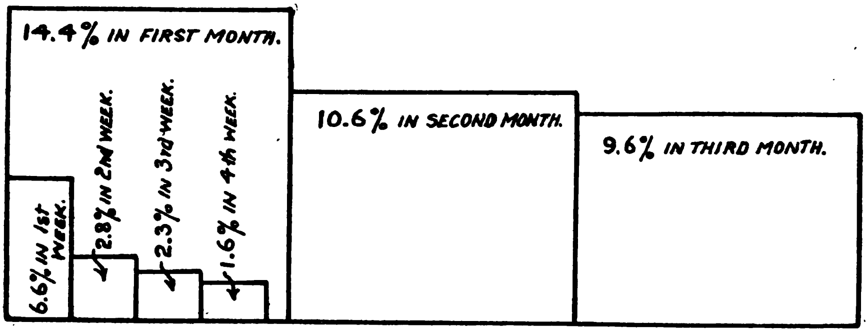
[1] U. S. Bureau of Labor Statistics, Bulletin No. 234, June, 1918. The Safety Movement in the Iron and Steel Industry, 1907 to 1917, pp. 162 and 131.

CHART 31.—*Total number of persons injured, subdivided according to length of continuous employment at ten-hour plant.*[2]

SAMPLE OF 600 CASES DURING SIX WEEKS.



DETAIL SHOWING SUBDIVISION OF PERSONS INJURED DURING FIRST THREE MONTHS OF EMPLOYMENT.



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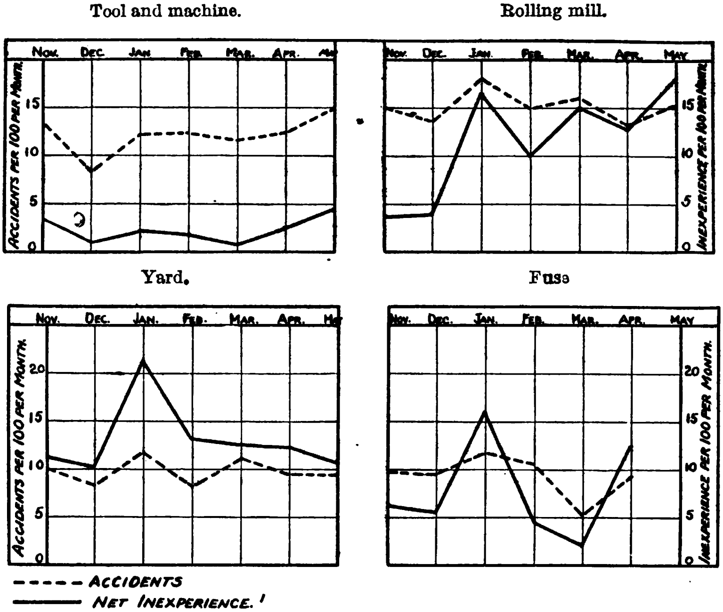
[1] Op. cit., pp. 134–136.

[2] For relation to working force see page 169 and chart 37.

CHART 32.—*Correlation of accident rate and proportion of inexperienced men during seven months of 1916–1917, in four largest departments of ten-hour plant.*



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[1] Net inexperience of a department is the percentage of men newly hired (men reinstated or rehired excluded) compared with the average number employed in the department as measured by three sample days in each month chosen at intervals.

CHARACTER OF HOURLY ACCIDENT CURVE NOT CHANGED BY INEXPERIENCE.

In the general accident figures of the present study it has not been possible to isolate the factor of inexperience; we are unable, therefore, to estimate how much it affects the total number at either plant. In a study of accident rates this would obviously be of prime interest and importance. For our special interest here, however, the distribution of accidents and of hourly risk during the working shift, it is not important. For the factor of inexperience, whether large or small, is always present, and whether large or small is constant throughout the day, not varying from hour to hour like the other elements in the causation of accidents. It will raise the level, not change the general character of the total accident curve, since for the inexperienced the ordinary strains and hazards of the successive working hours are simply intensified.

ACCIDENTS AND THE HIGH TURNOVER.

From the point of view of safety it is evident that beginners are undesirable employees. When a plant is undergoing expansion and labor recruiting is active, a rise of accidents disproportionate to the increase of the total labor force must be expected, since in all labor recruiting there is certain to be a large proportion of inexperienced workers. Thus, in the year from December 1, 1916, to December 1, 1917, the 10-hour plant, in order to increase its force by 2,215, hired 15,619 new men and rehired 7,082. For every permanent increase about seven times as many new men were hired plus about three times as many rehired workers.

Inexperience and its accompanying high accident hazard are inevitable at times of expansion and doubtless beyond a certain point irreducible. But the enormous chronic amount of inexperience shown by the high proportion of new workers, and the steady inflation of the accident rate by its presence are *not* inevitable. This is a grave aspect of the high turnover, and should prove a potent stimulus to its reduction. The menace of inexperience to a factory's safety can not be rightly estimated by the accident rate of inexperience alone; this rate must be studied in connection with the turnover. It is obvious that the import of such an accident rate as 111.3 per 1,000 new workers quoted above[1] (6 months' employment or less) will differ greatly according to whether 1,000 or 15,000 such new workers were employed in the course of a year. Only when the heavy hazard of inexperience is related to the number of employees yearly subject to it can we estimate its full menace in a given factory.

ACCIDENTS AND LIGHTING.

A subordinate element in the causation of accidents is generally admitted to be defective lighting. Through fatigue resulting from eye strain on the one hand and through the immediate risk due to the decreased visibility of danger points on the other, inadequate illumination directly favors a high incidence of accidents. No study of this hazard is included in the present report. Some interesting incidental testimony to the part played in accident causation by poor lighting is furnished by chart 29 showing the curves of accidents and power load at the 8-hour plant. We have already in the preceding pages discussed the composite accident curve in relation to power consumption during the three months of the Public Health Service study. On the lower part of the chart, as we have seen, the accident curve for each individual month is plotted separately, and on each of these curves the time of sunset, averaged for the month, is indicated by a star. In each month the rapid descent of the curve in the afternoon, due to the decreasing number of men at work, is abruptly checked within the hour and a half preceding sunset. In September and October the curves so arrested rise for an hour, reaching a sensible peak half an hour before sunset; in November the descent of the curve during the corresponding time is noticeably checked. It should be noted that the check in the descent of the accident curve about 4 o'clock and its rise about 5 o'clock may be accounted for at least in part by the fact that the exodus of the morning shift has ceased, that the afternoon shift is now well under way and beginning its work with the customary rise of speed accompanied by a rise of accidents. This explanation, however, is insufficient, and it is not unreasonable to associate the rise in accidents with the hour of twilight or imperfect illumination just before the growing darkness necessitates a complete lighting up of the factory. A prompter lighting up before sunset might well reduce this temporary increase of accidents.

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[1] Page 128.

NOTE A.

THE INFLUENCE OF FATIGUE IN THE CAUSATION OF ACCIDENTS AS SHOWN BY THE DIFFERENCES IN VARIATION OF ACCIDENTS AND OUTPUT.

The strict variation of accidents with output is most nearly approximated, as we have seen, in the figures of the first spell at the 8-hour plant, and in the earlier hours of machine work at the 10-hour plant. An ingenious explanation of this relation of accidents and output in machine work in metal-working plants is advanced by Vernon in his study of accidents.

He remarks that in lathe work and in similar machine operations there is a practically irreducible cutting time of the tools, in which no speeding-up is possible. The workers can speed up therefore only in handling the tools, that is, in clamping, unclamping, bringing tools into contact with the metal, etc., operations in which the possibility of injuries through cuts, bruises, etc., is great and obviously increased by greater speed.[1]

In such work, therefore, it is natural that the accidents should rise above output not in the relation of 1:1 but at a higher rate of increase. In machine work at the 10-hour plant, and at the 8-hour plant where machine work makes up 50 per cent of the activity of the factory, the variation is found to be approximately as 4:1.

In order to prove whether the effects of speed of production account for the more marked variation of accidents as compared with output, or whether some other factor than speed of production must be held to intervene, we have tested the divergence of the actual figures of accidents from the expected figures as they would be if the 4:1 relation to output obtained throughout and was calculated afresh for every hour on the basis of the previous hour, with the following results:

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[1] Health of Munition Workers Committee, Memorandum No. 21, p. 11: "A speeding up of 10 per cent may well induce an increase of 50 or 100 per cent in the number of accidents, because in most of the small lathe operations performed at a fuse factory this speeding up has to be done mainly by a quickening of the rate at which the fuse part is clamped in, or unclamped from, the lathe, and the rate at which the cutting tools (generally on a capstan) are changed and brought into contact with the metal surface. Not much speeding up of the actual cutting operations is permissible, so a given speeding up of output means a relatively much greater speeding up of the movements made at times when the workers are specially liable to knock their hands against the cutting tools."

In Table 29, line *a* gives the expected index numbers of accidents; line *b* the actual index numbers. In the last line *c* (equals *b/a*), showing the disproportion between the actual and the expected figures, every figure above unity indicates the intervention of the other factor in the causation of accidents, namely, fatigue.

Moreover, a further consideration is pertinent here. With increases in output, in any given period, the cutting time, being constant for each unit, will increase exactly in proportion to the total increase of output. Hence less time will be left for the variable part of the operation, though more output will be produced. The variable part of the operation will, therefore, take a steadily decreasing part of the total time necessary for the operation, and the difference in the time relation between variable and constant will be greatest at maximum speed.

In giving a constant rate of variation of accidents over variation in production (i. e., as 4:1) in the following table, we assume that no accidents happen during cutting time and that the operation is running near maximum speed. We have not attempted to represent graduated increases in rate of variation of accidents at different speeds.

TABLE 29.—*Index numbers showing relation of actual variation in accidents to expected variation according to 4 : 1 ratio.*[1]

Hours.	1	2	3	4	5	1	2	3	4	5
EIGHT-HOUR PLANT.										
Total.										
a. Expected accidents	......	129.6	136.2	118.6	......	......	116.2	113.4	136.5	......
b. Actual accidents	100	131.3	134.5	117.2	......	......	133.9	139.3	117.1	......
c. Ratio *b/a*	......	1.01	.99	.99	......	......	1.15	1.23	.86	......
TEN-HOUR PLANT.										
Total										
a. Expected accidents	......	130.8	132.0	147.9	110.0	129.8	117.1	122.6	133.4	38.4
b. Actual accidents	100	129.7	147.9	152.0	113.2	120.4	138.7	140.6	139.2	128.0
c. Ratio *b/a*	......	.99	1.12	1.03	1.03	.93	1.19	1.15	1.04	3.33
Machine work.										
a. Expected accidents	......	136.4	145.9	156.0	128.6	136.0	113.8	141.3	143.4	82.4
b. Actual accidents	100	132.0	147.1	156.9	140.4	117.6	148.5	149.1	154.8	152.0
c. Ratio *b/a*	......	.97	1.01	1.01	1.09	.86	1.30	1.06	1.08	1.85
Dexterous work.										
a. Expected accidents	......	140.0	137.7	139.1	125.4	129.4	121.9	145.2	143.8	52.5
b. Actual accidents	100	131.5	147.7	166.7	130.5	111.5	161.0	141.0	138.1	157.2
c. Ratio *b/a*	......	.94	1.07	1.20	1.04	.86	1.32	.97	.96	2.99
Muscular work.										
a. Expected accidents	......	117.6	141.3	182.5	126.6	238.8	113.2	137.8	158.5	(2)
b. Actual accidents	100	154.3	184.0	211.0	160.4	139.0	172.3	184.5	202.2	178.6
c. Ratio *b/a*	......	1.31	1.30	1.16	1.27	.58	1.52	1.34	1.28	.∞

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[1] The detailed calculation of the table is as follows:

Following the approximate variation at the 8-hour plant, and in machine work at the 10-hour plant, we will assume that accidents vary with output in the relation of 4:1.

Let $x\%$ = the variation of output of any given hour over the previous hour.

Then $4x\%$ = the corresponding variation of accidents.

Let y = the previous hour's accidents.

Then ($4x\%$ of y) + y = the accidents of the given hour. Thus in order to determine the expected accidents of the second hour in the 8-hour plant total, we find that $x\% = 7.40\%$, $4x\% = 29.6\%$, and $y = 100$. Then ($4x\%$ of y) + y = 129.6. For the third hour, $x\% = .93\%$, $4x\% = 3.72\%$, and $y = 131.3$. Then $4x\%$ of y = 3.72% of 131.3 = 4.9; and ($4x\%$ of y) + y = 4.9 + 131.3 = 136.2.

[2] Less than 00.

Thus in the whole first spell at the 8-hour plant, the variations from unity are negligible; accidents, that is, as we have said, vary practically with speed of production. In the second and third hours of the second spell on the other hand there is a marked rise of the actual over the expected variation (ratios 1.15 and 1.23), showing that the factor of fatigue has entered.

In the first four hours of machine work at the 10-hour plant the variations from unity are also negligible; in the fifth hour there is again a rise of the actual over the expected figure (ratio 1.09).

To explain this rise above unity, indicating fatigue, in an hour in which the accident chart in our text showed no rise of risk, we must carry Vernon's hypothesis a step further. If, by hypothesis, with increasing output accidents rise at a more rapid rate than output, owing to the speed of production, then, by the same hypothesis, with declining speed accidents must decline at the same more rapid rate than output. Where they do not so decline, the speed of production theory fails and fatigue must be admitted to have interfered with the parallelism of the curves. Thus in the fifth hour of machine work, declining speed should (with the 4:1 relation) reduce accidents to the index number 128.6. But they actually fall only to the index number 140.4. The disproportion between the two numbers shows the intervention of fatigue. The same explanation holds true of the fifth hour of the composite 10-hour chart. Here declining speed should reduce accidents to the index number 110. They actually fall only to the index number 113.2, showing again that the element of fatigue has intervened.

In the dexterous and muscular types of handwork the distinction between variable and irreducible time of performance obviously does not exist, in the absence of any fixed part of the operation. Yet in order fully to test Vernon's hypothesis we give the divergence of actual and expected figures in these types also, and for the 10-hour plant, as a whole, on the same basis of 4:1. The intervention of fatigue is again shown by the figures above unity in line *c*, the actual accidents being, except in the first hour after lunch, almost uniformly higher than the expected figures.

In dexterous and muscular handwork, however, the actual relation of accident and output variations would seem, by careful observation, to be more nearly on a basis of 1:1 or 1½:1 than the basis of 4:1, which is true of machine work. Under such a 1:1 relation, the ratio between actual and expected figures would, with rising output, be higher than it appears in this table because the disproportion between the figures would be greater; with falling output, the ratio would be lower than it now appears because the disproportion would be less. The hypothetical figures, in these types, therefore, understate the influence of fatigue while output is rising, and exaggerate it when output falls.

The speed of production theory, therefore, fails to account alone for the causation of accidents. That it is substantiated in certain hours, our figures have shown; that fatigue accounts for other hours would appear to be equally substantiated.

NOTE B.

TEN-HOUR PLANT.

I. Reliability of Accident Figures.

This analysis is of special interest in the face of doubts cast by recent official reports on the accuracy of hourly accident tabulations. Vernon, for example, frankly admits that his accident statistics are falsified by tardy reporting. Chaney considers that accidents reported from memory and with a probable bias toward certain hours may be sufficient in number to "materially modify the curve."

To test the accuracy of the 10-hour plant's records, the Public Health Service detailed an investigator during a given period to investigate all cases of accident brought to the hospital in the course of the morning hours. In each case the time of the patient's arrival was compared with the time of the accident's occurrence as recorded on the blank. Three hundred and twenty-two cases were thus examined; 256, or four-fifths of the entire number, arrived at the hospital within half an hour of the recorded time of injury. For all these the delay between the times of accident and arrival at the hospital averaged only 5.88 minutes. This very reasonable average for the time necessarily consumed in reaching the hospital from the various parts of the factory gives good assurance that no general tendency to delay falsifies the figures. The foreman, indeed, was found in many cases to have given not the actual moment of incidence but the nearest hour or quarter-hour, but such inaccuracies evidently average themselves out without affecting the hourly accident distribution.

The possibility remains that the foreman has recorded the time when the accident was reported to him rather than the time of its occurrence. To test this possibility, the investigator at the hospital questioned each injured person on his arrival as to the time of his accident. In only 75 cases was the patient able to give an exact answer. It is strong evidence of the foreman's essential accuracy that in these 75 cases the difference between the patient's statement and the foreman's record averaged only 0.8 of a minute. In more than half of them the times tallied to a minute.

In the remaining one-fifth of the 322 accidents examined, the patient arrived from half an hour to an entire day after the accident was recorded as occurring. In default of means of verifying the hour of incidence given, it suffices in so small a proportion of accidents to assure ourselves that the records show no tendency toward special hours capable of disturbing the distribution curve. No one hour was found by the investigation to show any marked preponderance. In 51 cases of delayed reporting in which the accidents were recorded as occurring in the 10-hour day shift, no single hour's record was found to deviate from the minimum by any appreciable amount and the two hours with the highest records, 4 to 5 and 5 to 6 p. m., were those in which the largest number of accidents delayed in reporting till the morning hours of the next day would have been likely to occur.

In case of these accidents, then, where the time of injury was recorded by the foreman and the time of arrival at the hospital noted by the investigator, no tendency to delay or bias affecting the essential accuracy of the records can be detected. These 322 cases may fairly be taken as a representative cross-section of the factory accident records.

One exception, however, must be noted. In a certain number of cases, roughly about 6 per cent of the total yearly accidents, the time of incidence is entirely omitted in the record. These accidents, instead of being classified as unspecified, are tabulated by a system adopted at the factory in 1917, according to definite hours. In the effort to determine the principle of this classification by a sample of 50 accidents, it was found that in 49 out of these 50 the hour assigned was the time of the report to the foreman. The generally prompt reporting of accidents in the factory, however, renders even in the case of these 6 per cent the average liability to error a comparatively small one.

According to our previous sample of 322 accidents, four-fifths of the total accidents in the factory arrive promptly at the hosptial. As only one-fifth arrive with any degree of tardiness, the liability to any serious error among these unspecified accidents would be only one-fifth of 6 per cent, or 1.2 per cent of the accidents in the entire factory. So slight a percentage of possible error can not be held to impair the practical accuracy of the accident records at the 10-hour plant for purposes of hourly tabulation.

II. METHOD OF OBTAINING REPRESENTATIVE PRODUCTION FIGURES FOR THE TEN-HOUR PLANT AS A WHOLE.

For the purpose of comparing operation with operation, type with type of work, and factory with factory under the 8- and under the 10-hour day, the classification into four types of work, each representing one-quarter of the activity of the factory, which was representative of the 8-hour plant (see p. 75), was adopted for the 10-hour plant as well. In order that differences in the output curves might not be attributed merely to differences in the character of the work, it was necessary, for this comparison, to select comparable operations in the same proportions at the second factory. This classification, however, does not correspond to the actual division of work at the 10-hour plant, where the extraordinary mechanical development of the 8-hour plant is lacking and hand work represents a much larger proportion of the whole. According to a census of occupations taken in the 10-hour factory in 1918, the total working force is subdivided among the several types approximately as follows:

	Per cent.
Dexterous handwork	35
Muscular work [1]	40
Machine work [2] (both lathe and miscellaneous types)	25

In order, however, to compare fairly the relation of accidents to activity, the factory must be represented by occupational groups which are fairly proportioned to the actual distribution of accidents. Our analysis of the relation of accidents to output and to fatigue might otherwise be criticised as misrepresenting the accident risk by including operations or departments in which few or no accidents occur, thus giving undue weight to operations not subject to accident and insufficient weight to operations where the hazard is high.[3]

Now, the distribution of accidents in the three types of work just given is roughly as follows:[4]

	Per cent.
Dexterous handwork	28
Muscular work	38
Machine work	34

The simplest weighting, therefore, of the three types, which will most closely correspond on the one hand to their respective percentages of total workers and output, and on the other to their respective proportions of accidents, is to value each as one-third in the composite output of the factory. The most considerable divergence from the third is that of the percentage of men in machine work, 25 per cent, but as relatively more accidents occur in this group it should properly be weighted somewhat more heavily than the census of occupations would indicate.

Moreover, to insure fairness of representation within the several types, the operations whose output curves are to be components of the group curves must be both typical of the group and proportionate to such subdivisions as may compose it. These conditions are fairly met in the case of the dexterous and muscular groups; the groups are fairly homogeneous and the operations studied are as representative as the range of selection allowed.[1]

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[1] Including machines driven by man power, such as foot press assembly, retap, etc.

[2] Machine helpers handling heavy materials, as distinguished from machine operators, are included in muscular work.

[3] Thus, the non-manufacturing force (office force, inspectors, etc.) which constitute 12.95 per cent of the total working force, is left out of account in this analysis, as being in effect subject to practically no accident hazard.

[4] Analysis by the Public Health Service investigators on basis of 322 accidents occurring in the last 3 weeks of August, 1918.

DIFFICULTIES OF REPRESENTING MACHINE WORK BY THE OUTPUT CURVE.

The third group, machine work, however, representing 25 per cent of the factory's activity, is made up, according to the factory census, of 58 per cent lathe work and 42 per cent miscellaneous machine work. The distribution of accidents among these subgroups corresponds very closely to the distribution of workers.[2]

Automatic machine work, a subgroup constituting about one-fifth of the miscellaneous class, is, however, not represented by any of the operations studied.

But the fundamental difficulty is found in representing the stereotyped operations common in machine work at the 10-hour plant. These operations were necessarily excluded from the output curves for the comparison with the 8-hour plant where no stereotyping occurs. But for a fair picture of the factory's activity and accident hazard, they must here be represented together with unstereotyped operations in the composite output. In the present stage of our study of the subject, it is impossible to determine whether the operations studied correctly represent the high degree of stereotyping which undoubtedly exists in this type of work.

It should be noted, however, that while stereotyping undoubtedly lowers the general level of output in these operations, it does not very materially affect the hourly distribution of output, and hence should not be held responsible for the rise of the accident-output ratio which occurs during the late hours of the day. Reference to the table of stereotyped operations (page 87) shows that the maxima and minima in these operations are distributed among different hours. In the average curve, indeed, the relative height of the ninth hour will tend to lower the risk in the late afternoon.

ADVANTAGES OF THE POWER CURVE TO REPRESENT MACHINE WORK.

In view of the difficulty of representing machine work at the 10-hour plant by a reliable curve of output, it seems wiser to adopt for this type the accurate measure of power consumption.[3] By including all machine operations at the factory,[1] the power curve solves the difficulty of representing fairly both the subdivisions of the type and the degree of stereotyping.

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[1] Representation in these groups was limited, however, by the fact that only repetitive operations producing a uniform unit of output could be used for this study. This limitation is especially true of muscular work.

[2] According to a sample of 230 out of 322 accidents, analysed in detail by the investigators.

[3] The only limitation of importance upon this accuracy is that the given power curve in the first and last hours of each spell probably somewhat overestimates the factory's activity. This is due to the fact that the hourly averages are based on readings taken at each quarter hour, and that the readings at 7 a. m., 12 m., 1 p. m., and 6 p. m. are omitted, because the inclusion of readings based on the first and last moments of work would lower the average of the respective hours unfairly. Their exclusion leaves the slack periods of beginning and ending work unrepresented in the average, which is therefore unduly raised. The error, however, is less than if the canceled readings were included.

We have, therefore, in Table 22, representing the accident hazard at the 10-hour plant, shown the activity of the factory by a combined curve of output and power thus composed:

	Per cent.
Output of dexterous handwork	33⅓
Output of muscular work	33⅓
Power consumption of machine work	33⅓

The composite curve will then be made up as follows. The hourly outputs of all operations under the first two types are reduced to percentages of the average hourly output. These percentages for the several operations under each type are in turn averaged to obtain hourly output figures for each of the two types as a whole. For the third type we use the power curve, expressed in hourly percentages of the average hourly power consumption. The percentages representing the activity of each of the three types are next averaged to obtain representative figures for the whole factory.

NOTE C.

THE THEORY OF ACCIDENTS ADVANCED BY THE HEALTH OF MUNITION WORKERS COMMITTEE.[2]

According to Dr. Vernon's theory, advanced in Memorandum No. 21 of the Health of Munition Workers Committee, accidents vary, as we have seen, mainly with speed of production. But they do not necessarily vary in the relation of one to one. In many operations an increase of a single unit of output may increase five or ten times the activity required of the worker, and in such cases they will obviously vary as 5 to 1 or as 10 to 1 (see page 132).

According to this hypothesis, then, the accident curve will follow the output curve in general form but not necessarily in steepness, accidents rising, it may be, five or ten times as fast as output.

LACK OF STATISTICAL PROOF.

If this theory is correct it must be capable of statistical proof. But such proof is not given. Vernon criticizes the failure of earlier studies to correlate accidents with output as a "fatal defect," and takes a step toward correlation by giving separate output and accident tables and by placing on the same graph both accident and output curves. The true mathematical measure on which to base conclusions as to the relations of accidents and output—the accident-output ratio—is, however, not given in the report.

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[1] It excludes only the very small percentage of man-driven machine work.

[2] Health of Munition Workers Committee, Memorandum No. 21, 1918. An Investigation of the Factors Concerned in the Causation of Industrial Accidents. H. M. Vernon, M. D.

It must further be noted that in regard neither to output nor to accidents do Vernon's data appear to furnish an adequate basis for testing his hypothesis.

THE OUTPUT DATA.

The production curves in Vernon's report are represented by curves of excess or variable power load. On three charts the hourly curves of accidents and production are placed in juxtaposition. One of these places together variations of accidents at one factory and of output at another, and hence offers no accurate or scientific basis for a comparison (fig. 5, Hourly Variations of Accidents at Factory D and of Output at Factory C). On another chart (fig. 2), for correlation with accident curves representing data covering 25½ months from November, 1915, to December, 1917, two output curves are given which represent "hourly meter readings" for only three consecutive days and nights in January and July, 1917, respectively. A third set of readings for the day shift during five days between April and June, 1916, added in Table 1, furnishes some check on the other two, and shows a similar distribution of output during the day at these different dates. But the meagerness of these data as compared with the data on accidents is striking. For another factory (factory B, fig. 4) the production curves given for correlation with curves representing the accidents of nine and a half months represent mean power variations for five consecutive days and nights in August, 1916, and three consecutive days and nights in August, 1917. The 1917 power record stops short at 3.30 p. m. and 3.30 a. m., "as some of the workers had to knock off owing to shortage of material," thus leaving out of account the part of the days' record most needed to test the theory. In contrast to these short periods of power readings the length of time taken by the Public Health Service investigators for a like purpose is worthy of note, namely, 29 days.

Exception may be taken, moreover, to the method chosen of representing output. The production curves given are, as we have seen, the curves of power consumption, i. e., of the "excess" power load or variable load, which varies with the activity of the workers. But the power curve, obviously, can measure only the output of machine operations.[1]

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[1] That power measures machine output accurately Vernon has shown (fig. 1) by checking the power records for a certain section of machine work in the fuse factory (A) by direct count of output for the same workers. Seven-eighths of the operatives in this section (170 women) were engaged in turning fuse bodies on lathes; the power records were averaged for five days chosen during a two months period, and with the resultant curve was compared the curve of average output obtained from a direct count of the output of 43 of these same women for one day each during the same interval but not always on the same day. The curves, as we should expect (with the exception of a half-hour for which a special explanation existed), are closely parallel.

It is properly used for the fuse factory (A, fig. 3), where cuts and eye accidents are assumed to affect lathe workers alone. But at the 6-inch-shell factory (B), where accidents are assumed to affect all factory workers, (as "all the workers ran a risk of cuts from tools or from handling shells"[1]), it would seem that operations of the dexterous or muscular handwork type must exist which are subject to accident yet in no way represented by the power curve. In so far, then, as accidents occurring in such operations are included in the accident records, the correlation with output is inexact.

THE ACCIDENT DATA.

The accident data in the report are by Vernon's own statement unreliable. In the absence of any system for noting the actual time of incidence an allowance of five and a half minutes is made as the average delay between time of occurrence and time of treatment. But the writer admits that "it is impossible to obtain a numerical measure of the extent to which inclination [i. e., the willingness or unwillingness of the workers to report promptly at the dressing station] will falsify accident statistics."[2] Since his investigation is based on existing factory records, Vernon was unable to take precautions to fix more accurately the time of occurrence on which the curves are based. He attempts to check the general inaccuracy of the reporting by constructing a standard curve obtained by classifying accidents so as to isolate injuries to the eyes. Such accidents obviously enforce prompt resort to treatment, and would therefore offer a correct record, but they are both too few in number and, by Vernon's own definition ("foreign bodies in the eye"), too independent of the human factor to furnish in other respects a standard curve. Vernon defends his use of this curve as a norm by the statement that the curve of eye accidents is dependent on the curve of production, because as speed increases the worker bends closer to his machine and incurs increased danger from flying particles, etc. This defense hardly suffices to give the curve the authority of a standard for all types of accidents, in most of which a larger human factor is involved. In addition, the inclusion of re-dressings or previous injuries largely impairs the value of the accident data.

HYPOTHESIS NOT SUBSTANTIATED BY DATA.

But even if we grant the validity of the accident and output data, the primary emphasis placed on speed of production is not substantiated by the facts. The hypothesis that accidents vary with speed of production, while generally borne out by the curves in figure 2, does not cover the fact that while output falls in the afternoon hour from

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[1] Op. cit., p. 13.

[2] Op. cit., p. 10.

2 to 3 p. m., the 1917 line of accidents for men rises, or that in 1916 the accident line falls sharply during the later afternoon with rising power, or that in figure 4 power falls from 12.30 to 3.30 p. m., but accidents (cuts) for both men and women rise.

HYPOTHESIS TESTED BY DATA OF PRESENT STUDY.

As we have shown in Note A, the hypothesis that the variations of accidents follow the variation of output is roughly borne out at the 8-hour plant and in the first spell of machine work at the 10-hour plant. The hypothesis, however, fails to account for the disproportionate increase of accidents over output in some hours even at the 8-hour plant, and in the afternoon spell of machine work and in dexterous and muscular handwork at the other factory. To explain these facts, other elements of causation must be sought.

OTHER FACTORS OF ACCIDENT CAUSATION.

Now Vernon admits the presence of these other elements; "the problem," he says, "is one of extreme complexity."[1] Leaving out of account the less important influences of lighting, nutrition, temperature, and alcohol consumption, the most important subsidiary influence is that of fatigue. Fatigue, which under a normal system of production is practically discounted by Vernon in relation to men's accidents and minimized for women's, is admitted to be the causal factor in women's accidents in the so-called "fatigue period" of the 12-hour day and 75-hour week worked in 1915. Here indeed the part played by fatigue is spectacular and undeniable; women's accidents in this period "were 2½ times more numerous than in the subsequent 10-hour day period but the men's accidents showed no difference."[2] In figure 2 the disparity of the 1915 curve of women's accidents with that of 1916 or 1917 is extraordinarily striking. That fatigue was the causal factor in the difference is proved by the fact that after February 1, 1916, when hours were shortened to 10 daily, the number of accidents was more than cut in half. Even with the 10-hour day the greater fatigue of women as compared with men on the 12-hour day is shown by the steeper rise of the accident curve and the preponderance of afternoon over morning accidents.

But the influence of fatigue which is held unimportant in relation to the hourly accident curve, except under circumstances of abnormal strain, is given its due weight in relation to the weekly incidence of accidents.[3] In analyzing the weekly curve Vernon holds that "several conflicting factors" are at work. The curve of speed of production rises and falls during the week, reaching its highest level toward the end of the week and tending to carry the accident curve with it. "Practice-efficiency" on the other hand, improving through the week, tends steadily to lower accidents. Fatigue, rising throughout the week, tends to raise accidents, but at the end of the week may be so great as to lower output and thus lessen accidents. The weekly accident curve, in Vernon's opinion, is the result of these various factors pulling against each other.

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[1] Op. cit., p. 22.
[2] Op. cit., p. 46.
[3] Op. cit., pp. 15 et seq.

The minimizing of fatigue and the attributing of undue influence to the speed of production in this report may be definitely accounted for. In choosing the output of machine operations alone to correlate with accidents the writer has chosen the type of work of all others which gives least evidence of fatigue in the output curves, and in which his theory of the dominant influence of speed of production is best illustrated. That fatigue may influence the causation of accidents in other types of work he indicates only by the parenthetical remark that if men "worked 12 hours or less on heavier types of work than those imposed on them in the fuse factory they would doubtless be liable to fall into the condition of excessive fatigue shown by the women."[1]

NOTE D.

THE THEORY OF ACCIDENTS ADVANCED BY THE UNITED STATES BUREAU OF LABOR STATISTICS, 1918.[2]

We have seen that the Bureau of Labor Statistics as far back as 1911 offered an accident hypothesis combining speed of production and fatigue as the main determinants of the accident risk. That this hypothesis contained the essential truth, but that it remained unproved, failed of its due effect in the discussion of accident causation, and was later withdrawn by its author we have already attempted to point out. The report of 1918 on the safety movement in the iron and steel industry added coordination as an essential factor in the causation of accidents, but practically withdrew fatigue, except in so far as it may influence the "period of recoordination in the morning."[3]

Such a change of front was clearly not the intention of the writers at the beginning of their investigation. The study of accident distribution through the working hours "was primarily undertaken with the idea of discovering its possible relation to the problem of fatigue, and so contributing to the determination of the length of a reasonable working day."[4]

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[1] Op. cit., p. 26.

[2] U. S. Bureau of Labor Statistics, Bulletin No. 234, June, 1918. The Safety Movement in the Iron and Steel Industry, 1907-1917.

[3] Op. cit., p. 163.

[4] Op. cit., p. 154.

They were forced to conclude, however, that "it is not possible to show that fatigue is anywhere distinctly registered in the curves that have been plotted."

For this withdrawal of fatigue from the accident hypothesis, there is very definite reason. Lack of the necessary statistics of output made it impossible in 1911 to verify the parts played in accident causation by the two factors, speed of production and fatigue, advanced by the report as dominant. In 1918 the peculiar character of the output data secured made the withdrawal of fatigue inevitable; for the discussion of the relation of accidents to output proceeds here on the basis of an output curve, assumed to be typical, steadily rising throughout the working period or even throughout the day. From the facts at hand, the case is not "the simple one of rising accident rate with increased speed," but "the apparently contradictory situation of product rising and accidents responding for a time, while later with still rising product accidents decline."[1] On such a rise of production the "provisional explanation" of the report is based.

Coordination is advanced as the key to the problem. According to this explanation, output rises as coordination improves in the course of the morning's work; since there is little loss of adjustment during the noon interval, output continues to improve in the afternoon. While adjustment is still imperfect, increasing speed causes a more rapid increase of accidents; as faulty coordination is overcome, accidents decline.

With regard to the accident data, the writers of the report are alive to the danger of error connected with variation of employment and the lack of definite correlation of accidents with a number of workers constant from hour to hour. It is possible, they say, that the peak of accidents corresponds with the peak of employment and that the larger number of accidents is a response simply to the larger number of workers. Further uncertainty attaches to the question of correctness of record, in the absence of means of checking the times of accident occurrence. In the presence of these undetermined elements, they consider, "final conclusions regarding the significance of the distribution curves are not possible." [2]

So far as output data are concerned, the theory of accident causation is based solely on two tables and two charts.[3] For the first table, says the report, "the experience of press hands was assembled." This table may be dismissed from consideration owing to its artificial construction and the fact that, first, output and accidents not of the same establishments are compared and, second, that the output of one hour is compared with the accidents of a different hour. Obviously such a table can not be used as the basis of any tenable hypothesis.[1]

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[1] Op. cit., p. 159.

[2] Op. cit., p. 155.

[3] Op. cit., pp. 157-160.

The second table gives production figures taken from factory records during a period of seven months in nine mills of a steel plant. These figures show that in six out of nine mills the peak of production occurred in the eleventh hour; in two more in the tenth; while in the remaining mill maximum production was reached in the tenth and maintained through the eleventh hour.

Reference to the composite chart representing 12,407 300-day workers on the day turn also shows that the maximum was reached only in the twelfth hour after a steady rise throughout the day. Drawn beside this steadily rising output curve, the accident curve rises irregularly till the hour from 9 to 10 a. m. and sinks again till noon. After the noon break it rises sharply to its maximum between 1 and 2 o'clock but from that point declines gradually till the end of the afternoon.

If such a curve of production as that of the steel plant is representative, it is clear that the fatigue factor in accident causation is either absent or masked, and must be barred from the hypothesis. The attempt made in the report to show the correlation of accidents with output by the physical juxtaposition of tables and curves, even without the accident-output ratio, makes it readily apparent that these curves of rising output and falling accidents would give us toward the end of the spells a steadily diminishing accident risk. But are these curves representative?

In contrast with these factory records of output, we may offer the detailed first-hand study presented in chapter 2 of the present report. Now the salient feature of the output curves studied in chapter 2, individual and composite, for operations, types of work, and entire factories, is the fall of output toward the end of each spell, the more marked fall at the end of the day, and its lower level in the afternoon than in the morning. Machine work as a whole offers the most sustained type of curve; within the group certain operations conditioned in large part by furnace processes and thus reflecting mechanical conditions rather than human capacity, show an exceptional curve not reaching its highest point till the end or almost the end of the afternoon. (The curve of stereotyping, which generally reaches its maximum toward the end of the afternoon, is here left out of account.) It is possible that similar operations preponderate in the curve for the steel plant and determine its peculiar form.

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[1] Accidents are taken from the report of 1911, p. 96. This table represents the accidents of 19 establishments obtained for an average period of 3½ (3.47) years, calculated on a yearly basis, or of 51,908 workers for a single year. In the 1918 report, the accidents of the first hour (7 to 8) and of the last hour (5 to 6) are omitted without stating that the omission has been made. The hourly records are then tabulated and charted under the captions, first hour, second hour, third hour, etc., as if they constituted two 4-hour spells and as if the second to fifth hours, inclusive, of the morning corresponded to the first to fourth hours, inclusive, of the afternoon.

For correlation with these accident figures representing 19 establishments, the production figures represent operations of 23 machines during 1 to 7 days in a single factory only. The figures are obtained as follows: The output of the hours 7 to 8 and 8 to 9 are each halvod and the halves are added, thus obtaining the output for 7.30 to 8.30 (18,815½ + 19,927½ = 38,744). This output figure is tabulated and charted under the caption "first hour" in juxtaposition to the accidents of the hour 8 to 9, also called "first," and so on for the remaining hours.

It is impossible, we must conclude, to accept as generally valid a hypothesis of accident causation based on a special and even exceptional type of output curve. But even in the case of the steel plant chosen the hypothesis is not an adequate explanation of the fact advanced. Coordination, steadily improving, is held to explain the steady rise of output and the decline of accidents in the later hours of the spell and day, and coordination is used in apparently the same sense as practice. This explanation, depending on a steady increase in practice throughout the period of a 12-hour day, does not commend itself as reasonable.

CHAPTER 6.

OUTPUT OF THE TWELVE-HOUR NIGHT SHIFT.

Under the 10-hour system, a 12-hour night shift is the rule. The chief characteristics of the 12-hour night shift are the abrupt fall of output in the last two hours and the progressive slowing in rate of production during the night.

Prominent among the factors to be considered in any study of night work are two: the length of the night shift and the special effects, if any, of work done in the night-time inverting the usual order of life. Previous studies of night work agree in the opinion that for men as well as women night work is physiologically undesirable.[1] It has been shown that the rate of accidents is higher by night than by day;[2] that more time is lost by night workers than by day workers;[3] that the output of night work is less than that of day work in many operations studied, though when comparatively short periods of day and night work were regularly alternated the output by day was practically equal to that by night.

The Public Health Service investigation of night work, while confined to certain specific points, has confirmed these earlier studies in some important particulars. At the 10-hour plant sufficient data were obtained to yield definite conclusions on the relation of the 12-hour night shift to production. Facts bearing on the special effects of night work on the activity of the workers were also obtained. The results of the observations are presented in Table 30 and chart 34. At the 8-hour plant the number of operations studied was too limited to establish conclusions.

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[1] The Case Against Night Work for Women. The People of the State of New York *v.* Charles Schweinler Press. Louis D. Brandeis and Josephine Goldmark. National Consumers' League, New York. Revised to 1918.

[2] Report of the U. S. Department of Labor on Conditions of Employment in the Iron and Steel Industry in the United States, vol. 4, Accidents and Accident Prevention. Senate Document No. 110, 62d Cong., 1st sess., 1913, pp. 152–156. Bulletin of the U. S. Bureau of Labor Statistics, No. 234, 1918, pp. 146–152. The Safety Movement in the Iron and Steel Industry, 1907 to 1917,

[3] Health of Munition Workers Committee. Interim Report, 1917. Industrial Efficiency and Fatigue, pp. 26 to 40.

TABLE 30.—*Ten-hour*

Operation.	Number of observations.	Starting time of shift.	Period of study (days).	(a) Number of units; (b) Index numbers.[1]	Average output observed each working hour.				
					1[2]	2	3	4	5
Face, drill and ream	117	6.20 p. m.	32	(a)	183	208	216	210	208
				(b)	84.7	96.3	100.0	97.2	96.3
Spin top cap	70	...do	24	(a)	148	170	179	178	176
				(b)	82.7	95.0	100.0	99.4	98.3
Drill three holes	54	...do	28	(a)	362	385	373	371	353
				(b)	94.0	100.0	96.9	96.4	91.7
Drill six holes	62	...do	23	(a)	236	255	259	272	253
				(b)	86.8	93.8	95.2	100.0	93.0
Drill four holes	130	...do	27	(a)	189	176	180	179	179
				(b)	[3]105.0	97.8	100.0	99.5	99.5
Average index numbers					90.6	96.6	98.4	98.5	95.8

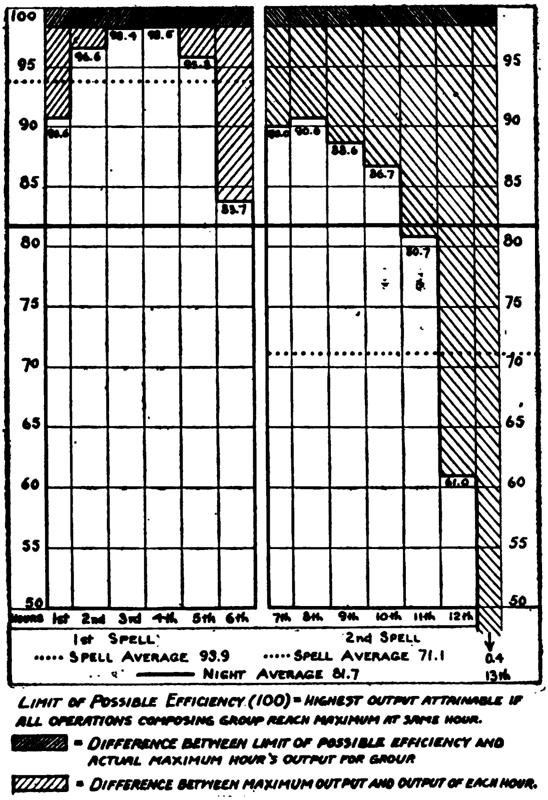
[1] Index number = percentage variation from maximum; maximum = 100.
[2] Period of 40 minutes. Actual output multiplied by $\frac{60}{40}$.
[3] Period of 40 minutes. See p. 28, footnote.

plant, night work.

Average output observed each working hour.										Average for night.	Ratio of second spell to first spell (in per cent).
6	Average for spell.	7[2]	8	9	10	11	12	13[3]	Average for spell.		
197 91.2	204 94.4	200 92.6	207 95.8	202 93.5	196 90.7	181 83.8	128 59.3	1.3 0.6	159 73.6	180 83.3	78
157 87.7	168 93.9	155 86.6	159 88.8	164 91.6	170 95.0	160 89.4	144 80.4	1.4 0.8	136 76.0	151 84.4	81
262 68.1	351 91.2	332 86.2	320 83.1	306 79.5	291 75.6	247 64.2	158 41.0	0.0 0.0	236 61.3	289 75.1	67
228 83.8	250 91.9	232 85.3	249 91.5	229 84.2	221 81.3	208 76.5	176 64.7	0.0 0.0	188 69.1	217 79.8	75
158 87.8	177 98.3	179 99.5	169 93.9	170 94.4	164 91.1	161 89.4	107 59.4	0.9 0.5	136 75.6	155 86.1	77
83.7	93.9	90.0	90.6	88.6	86.7	80.7	61.0	0.4	71.1	81.7	76

CHART 34.—*Index numbers showing percentage variations of hourly output from limit of possible efficiency.*

TEN-HOUR PLANT—NIGHT WORK TYPE.



THE TWELVE-HOUR NIGHT SHIFT AT THE TEN-HOUR PLANT. COMPARISON WITH THE DAY SHIFT, SPIN TOP CAP.

Night work at this plant runs 12 hours and 20 minutes, from 6.20 p. m. to 6.40 a. m., with a recess of 20 minutes at midnight.

The only process studied on both day and night shifts is the lathe operation known as spin top cap, already described on page 62. The quantitative output of the night shift can not be compared with that of the day because the same workers were not employed. Thus the maximum hour's output in the operation averaged 220 fuse tops by day and only 179 by night. The average output for the two spells of each shift and for the entire shifts are as follows:

	Day.	Night.
Average output, first spell	197	168
Average output, second spell	206	136
Average output, whole shift	202	151

It is clear that these absolute numbers can not be properly compared, since they may represent merely differences of efficiency in the day and night workers, due to other causes than the contrast of day and night. A fair comparison can, however, be made between the index numbers for the several hours representing the relative fall from maximum, irrespective of the absolute output, in the day and night shifts.

Thus the curve of night work in spin top cap (chart 33) shows a far more marked decline from the maximum hour than does the daytime curve in this process (see p. 62). During the last forty minutes there is almost total cessation of output. The fall from maximum in the final hour of the first and second spells of each shift, shows the following contrast:

	Day.	Night.
Fall from maximum, first spell (points)	2. 7	12. 3
Fall from maximum, second spell (points)	6. 8	99. 2

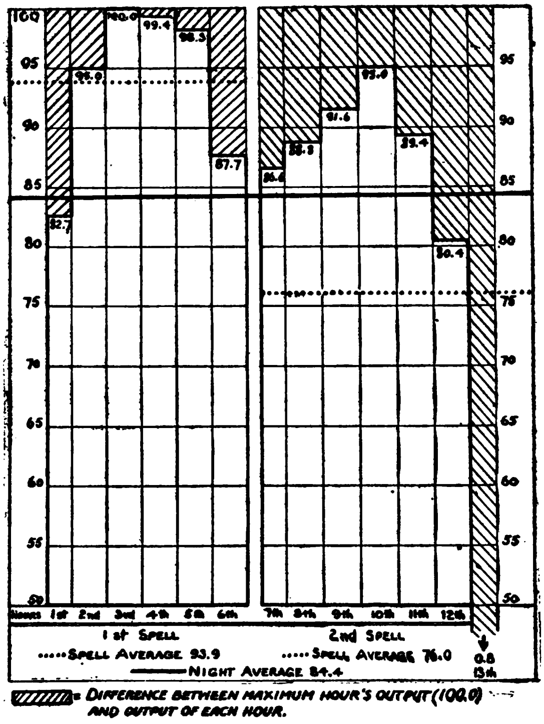
Even if we disregard the last period of the night when practically no work is done, the penultimate hour falls 19. 6 points from maximum as against a fall of 6. 8 points in the corresponding hour of the day shift.

These heavy losses are the more striking because lathe work as we have seen, shows by day little loss of working capacity either morning or afternoon and maintains itself after the extraordinary rise from practice at an almost even level. The longer spells at night show the typical drop of fatigue. Maximum is reached more quickly than by day, in the third instead of the fourth hour of the first spell, and output continues high for two hours more. The additional sixth hour shows a loss of 10. 6 points from the preceding hour as contrasted with a loss of only 2. 7 points between the last and penultimate hours of the first spell on day shift. In the second spell, even if we again omit from consideration the last 40 minutes the fall of the twelfth from the eleventh hour is 9 points as against a difference of only 0. 4 points between the final two hours of the day shift.

Chart 33.—*Index numbers showing percentage variations of hourly output from maximum hour's output.*

TEN-HOUR PLANT—NIGHT WORK.

SPIN TOP CAP.



THE MIDNIGHT RECESS.

Probably this abrupt fall and actual stoppage of work at night is hastened by the shortness of the midnight recess, which lasts only 20 minutes, in contrast to the full hour's break at noon. It is true that the hour immediately after the 20-minute recess in spin top cap shows a slighter decline of output than the hour following the noon interval. As we have seen, at the 10-hour plant in all daytime operations demanding merely the exertion of muscular strength, the benefit of the hour's lunch interval is clearly evidenced by the sheer increase of output immediately afterward. On the other hand, in operations like lathe work in which coordination and practice play a large part, the period immediately after the hour's rest often registers a decline. The loss of practice following the interruption masks for an hour the benefit of the break in affording recuperation and stemming the onset of fatigue. This benefit is not evident until later, when practice is again, at least in part, regained and the recuperation obscured in the first hour makes itself felt.

The shorter recess at night favors the retention of practice in the first part of the second spell, but the lack of sufficient recuperation acts with the long hours in hastening the precipitous drop of output noted above, between 5 and 6 o'clock in the morning. In two of the four other operations studied on the night shift the retention of practice is shown only in the first period of 40 minutes after the midnight recess; in the two other processes, it is carried over into the next period of an hour. Thereafter the descent is continuous.

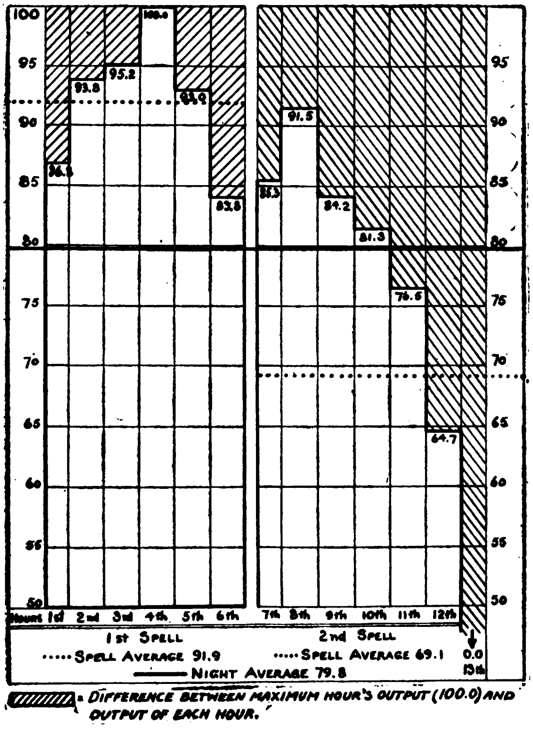
OTHER OPERATIONS.

The other lathe operation, face, drill, and ream, and the three drill processes studied on the night shift exhibit curves similar to that of spin top cap, but with an even greater failure of output in the last two hours. Again dismissing from consideration the last 40 minutes in which actually no work at all is done in two processes and a negligible fraction in the others, the fall of the twelfth from the eleventh hour, which averages, as we have seen, 9 points in spin top cap, here ranges from 11.8 to 30 points.

CHART 35.—*Index numbers showing percentage variations of hourly output from maximum hour's output.*

TEN-HOUR PLANT—NIGHT WORK.

DRILL SIX HOLES.



The character of the drill work curves, it should be noted, is affected at night as well as in the daytime by the existence of more or less of the stereotyping or fixing of output, generally prevalent at the 10-hour plant. The stereotyped curve at night differs, however, from the typical curve of the day. Instead of working below capacity throughout the first spell with a spurt to make up the required stint before the last hour of the afternoon, the operatives reach their maximum output at night in the first spell, sometimes after only one hour's work. In the operation of drilling six holes in the brass cap of the fuse (chart 35), maximum is reached somewhat later, in the fourth hour; but after the midnight recess output drops continuously in all these processes, with only slight occasional rallies, and ends with an even more spectacular fall than in spin top cap. The ratios of the second to the first spell—ranging from 81 in the unstereotyped operation of spin top cap to 67 in drill three holes—are all lower than in lathe work by day or any other type of work. The consciousness of having finished the required stint, together with the growing fatigue of the long shift, steadily lowers production.

SOME EVIDENCE OF THE SPECIAL EFFECTS OF NIGHT WORK.

TIME LOST EATING AND SLEEPING.

According to the Martin spring-balance muscle test, night workers at the 10-hour plant are physically inferior to the day workers. The night workers tested averaged 500 pounds less in muscular strength than the day workers.[1] How far night work was responsible for their physical inferiority could not be proved without prolonged observation of their health while at such employment. But a study of their actions during the 12-hour night shift shows the repeated interruptions of work due to the need of sleep and recuperation. One of several detailed studies was made on the night of August 6, when normal weather conditions prevailed, the temperature at 5 p. m. being 75° F. Fourteen men were observed, namely, four on the top cap operation, five on the drill four holes, and five on odd jobs, with the object of ascertaining the time lost in eating and sleeping. Of these, only three neither ate nor slept during working hours. One man was found eating at 9.45 p. m. and again at 10, another at 10.45 and 11, another about 11.45, and a fourth at 4 a. m. A fifth man was sleeping at 4.45 and again at 5.30, a sixth at 3.45 and 4, a seventh at 3.45 and again at 6, an eighth at 5, a ninth at 6, and a tenth and an eleventh man each at 6, 6.15, and 6.30.

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[1] For description of this test, see p. 46.

On the night of August 8, the weather being again normal, a count made of the number of men asleep each quarter of an hour toward the end of the night shift showed as follows:

Hour, a. m.	Number of men sleeping.	Hour, a. m.	Number of men sleeping.
3.30	5	5.15	2
3.45	3	5.30	2
4.00	4	5.45	4
4.15	0	6.00	2
4.30	4	6.15	14
4.45	1	6.30	2
5.00	5		

Seventy-four men were under observation, 42 per cent of whom were found asleep at different times between 5 and 7 o'clock.

The proportion of lost time on the hot nights of July 31 and August 1, 1917, when the temperature rose to 98° F. at 5 p. m., was far worse than this, but abnormal conditions in no way due to the factory management are not within the scope of this report.

SLOWING OF RATE OF OUTPUT.

Another significant fact observed on the night shift for which we have no corresponding data by day is the progressive slowing of the rate of output during the night, through the increase of time required for each operation. A time study made during the night of August 10, 1917, of men engaged in fuse drilling and lathe work showed that during the course of the night, the length of time taken to perform six separate operations increased nearly one-half. They averaged 12 seconds each in the first three hours, 13.3 seconds in the second three hours, 16.5 seconds in the third three hours, and 17.4 seconds in the last quarter of the shift.

Thus the economic waste of the last hours of the 12-hour night shift is established. To reach further conclusions as to the comparative efficiency of day and night work would need a study of the actual output of the same individuals working under the same schedule of hours by day and by night and under conditions of work and living otherwise similar.

CHAPTER 7.

LABOR TURNOVER.

1. Labor turnover is directly associated with distasteful working conditions, such as long hours, low wages, and undesirable physical surroundings. It is lowered by systematic effort to improve conditions and fit the workers to their jobs.

2. Turnover is highest among new employees.

As we have seen in a previous chapter, inexperienced workers, new comers, are, from the point of view of safety, undesirable employees. The safety-first movement itself is no more important for the reduction of accidents than is a deliberate and systematic effort on the part of the management to hold its labor force.

THE COST OF LABOR TURNOVER.

In estimating the costs of labor turnover not only those due to increased accidents, but also the huge losses to production, must be taken into account. These losses direct and indirect were well known before the war drew public attention to them.

An authoritative investigation showed, for instance, that of all employees hired in 12 metal factories in the year 1912, 72.8 per cent were entirely new; to increase the working force by 6,697 during the year 1912, 42,571 persons were hired, including both entirely new employees and rehired men.[1]

The cost of such great shifting of labor is due to many items, such as the expenses of hiring, instruction of new employees by foremen and others, increased wear and tear on machinery and tools, reduced production, the greater amount of spoiled work, and the increased accidents of inexperienced workers. The average cost of "hiring and firing" is estimated to be $53.92 for each new employee, ranging from $33.50 for one of the clerical force to $85.30 for a piecework operative, who can become efficient within a few months. For a new worker of this type $31.80 is assigned as the cost of reduced production, $20 for wear and tear, and $20 for instruction. Alexander estimated that the unnecessary shifting of labor within one year in the factories under investigation involved an economic waste of more than $1,000,000, or nearly 3½ per cent of the total pay roll of these 12 factories.

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[1] U. S. Bureau of Labor Statistics, Bulletin No. 227, p. 15. Proceedings of the Employment Managers Conference. Philadelphia, 1917: The Cost of Labor Turnover, Magnus W. Alexander, General Electric Co.

According to another careful estimate, the cost of "breaking in a new man" in one department of an efficient machine shop is placed at $65.40, but in view of the fact that six men are hired for one who stays long enough to become skilled "the final cost per experienced man" is found by the records of total excess costs to be over $100.[1]

No statistics of labor turnover are available for the country as a whole, but judging from these and other estimates, the dead loss to the nation's industry is enormous from this cause. The costs to the workers themselves from excessive shifting are scarcely less great. Prof. Willets, in his well-known report to the director of public works of the city of Philadelphia, enumerates them at length. They may be summarized as follows: A serious reduction of the wage scale owing to irregularity of work; the discouragement of thrift because when wages are irregular expenditures can not be planned in advance; a decrease in efficiency and steadiness of application; and worst of all a general lowering of the standards of living, increased debts, and exhausted savings.[2]

RELATION OF TURNOVER TO UNDESIRABLE WORKING CONDITIONS.

On all these accounts the reduction of labor turnover is a highly urgent problem of industry. One of its important but comparatively neglected aspects is the relation of the conditions of employment to the stability of the labor force. While the effect of undesirable environment in raising the turnover rate has frequently been pointed out,[3] no statistics appear to have been published dealing specifically with the subject. In the course of the Public Health Service investigation some exact data were obtained at both plants on the relation of working conditions to the rate of turnover.[1]

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[1] Op. cit., p. 173. An Actual Account of What We Have Done to Reduce Our Labor Turnover, John M. Williams, secretary of Fayette R. Plumb (Inc.); president Philadelphia Association for the Discussion of Employment Problems.

[2] Annals of the American Academy of Political and Social Science, May, 1916. Supplement, Pt. II, p. 37: The Unemployed in Philadelphia. Joseph H. Willets.

[3] Annals of the American Academy of Political and Social Science, May, 1917, p. 82. The Standardization of Working Essentials, Lillian Erskine, Investigator of Occupational Disease, New Jersey Department of Labor, in collaboration with John Roach, chief of the Bureau of Hygiene and Sanitation, New Jersey Department of Labor:

"Next to the questions of wage, hours, and the substitution by the management of a spirit of cooperation for the military spirit of command, no factor contributes more to the reduction of the labor turnover than that of sanitary and hygienic working surroundings. * * *

"But the steady force in the regulated industry can only be made up of men capable of giving service six days out of seven. Moreover, they must give a uniform service that guarantees a steady, rather than fluctuating, flow of production. And since the effect of the working environment upon the body of his employees is of incalculable importance to the employer, the standardization of hygienic essentials must be ranked by him with the questions of wage and hours, if the wastage of the turnover is to be satisfactorily eliminated from his plant."

Bulletin of the U. S. Bureau of Labor Statistics, No. 227, p. 50. Proceedings of the Employment Manager's Conference, Philadelphia, 1917. The Tabulating of Labor Turnover, E. H. Fish, employment manager, Norton Co., Worcester, Mass., chairman, Committee on Labor Turnover of the Employment Managers' Association of Boston:

"Under the head of 'Heavy, wet, or dusty, etc.,' of course, are included conditions which are ofttimes inherent in the business itself, and which must be faced. Sometimes, however, the fact that we are able to show to the management that a larger percentage of people than they had supposed leave us on account of these reasons may indicate to them the desirability of spending considerable sums of money in remedying conditions which they had been inclined to think were of comparatively little importance."

LABOR TURNOVER AT THE EIGHT-HOUR PLANT.

The labor turnover at the 8-hour plant was unusually low, 30 per cent in the year 1916–17.[2]

To reduce the labor force by 3,321 during the year, only 13,766 workers left, that is, about four times as many left as the total reduction of the force. High wages and short hours have been two of the factors which have brought about this result.

The introduction of a system of profit sharing at this plant a few years ago, at a time when the number of men leaving was very high, effected a revolution and almost wiped out the turnover in the following year.

A minimum of $5 per day is paid to every man or woman of 18 years or over, skilled or unskilled, who has worked at the plant six months or more. This wage, relatively much higher when adopted a few years ago than it is to-day, in combination with the short working day has continued to attract men to the plant and inclined them to remain. A further and highly effective hold on them is gained by the conscious effort of the management to fit every worker to his job, physically and temperamentally.

ADAPTATION OF THE WORKERS.

The preliminary physical examination compulsory for everyone applying for a job at the 8-hour plant at the time of the investigation lowers turnover by lessening the chances of injury and industrial disease. The aim is to detect physical disabilities before employment and place men where there will be the least chance of further injury. Thus men with weak hearts or hernia are put at work which does not require heavy lifting; men with weak lungs, at work free from dust, etc. In many cases this physical examination may have been hurried and imperfect, since the doctors were sometimes obliged to report on 200 men in a single day. But the system is far removed from the ordinary haphazard methods of hiring,[3] and is a long step forward in the direction of selecting workers in accordance with their physical capacities.

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[1] For turnover by departments, but without characterization of the working conditions in the department, see Monthly Labor Review of the U. S. Bureau of Labor Statistics, March, 1919, p. 35. Labor Turnover in Cincinnati, Emil Frankel. April, 1919, p. 23. Labor Policies and Labor Turnover in the California Oil-Refining Industry, Paul F. Brissenden, Ph. D. P. 53. Labor Turnover in Milwaukee, Wm. F. Kirk.

[2] Turnover rate equals ratio of number of persons leaving who are replaced to average number employed for a given period of time. For discussion of methods of calculating turnover see note at end of chapter.

[3] For proportion of plants requiring physical examination, see Hiring the Worker, Roy W. Kelly. Engineering Magazine Co., New York, 1918, p. 32, chart. Of 30 firms employing 55,850 employees only 7 firms had physical examinations.

Along the same line of adaptation is the extensive transfer system in this factory. A man who is unsatisfactory or dissatisfied may be transferred to another department instead of leaving the plant. Transfers are granted by the medical department for physical reasons; by the other supervising agencies for other causes, such as exigencies of production or trouble with the foreman, etc. In the effort to secure regularity of attendance investigators are sent to see the men in their homes after three days' absence, and the rule is to dismiss them if absent 10 days, except for good reason.

Yet even at this plant, which combines the attraction of short hours and high wages with a careful personnel management, it is highly significant that so large a proportion of men leaving left because of dissatisfaction with the conditions of employment. From figures kept at the 8-hour plant an unusually complete enumeration was obtained of reasons given for terminating employment (Table 31). This table covers 90 per cent of the total number of men (13,756) leaving in the 12 months ending September, 1917. Aside from those dismissed for special reasons peculiar to the year studied, such as military service, etc., almost 40 per cent, or more than 5,000 men, left because "dissatisfied with factory conditions."

TABLE 31.—*Number and percentage of employees absent from or leaving eight-hour plant.*

[Grouped according to specific reasons.]

	Men leaving October, 1916–September, 1917 (12 months).		Men absent Jan. 15–May 25, 1916 (113 working days).	
A. Reason not known to firm	732		16,989	
B. Reason known to firm	13,024		20,271	
		13,756		37,260
I. Special reasons of period or firm:				
(a) Transfer to Government or military service	1,678			
(b) Reduction of labor force	897			
(c) Transfer to branches	142			
(d) Special leave of absence	61			
		2,778		
II. General reasons		10,246		
	Per cent.		*Per cent.*	
(a) Employee dissatisfied with factory:				
(1) With job	32.1		1.2	
(2) With night work	3.7		.4	
(3) With organization	2.9			
		38.7		[1]2.9
(b) Employee dissatisfied with locality		8.7		
(c) Firm dissatisfied with employee:				
(1) Chronic absence, drink, etc	14.0			
(2) "Undesirable"	2.7			
(3) Technicality in factory system	1.1			
(4) Convicted of crimes	2.4			
		20.2		
(d) Personal reasons of employee:				
(1) Death	1.2			
(2) Sickness	8.3		75.5	
(3) Business and family circumstances	1.6		21.6	
(4) Bettering status	20.7			
(5) Migrating home	.7			
		32.5		97.1
Total		100 (100%=10,246)		100 (100%=20,271)

[1] Including miscellaneous dissatisfied.

THE CONDITIONS OF LABOR AND THEIR EFFECTS.

In the attempt to gauge the effects of environment, the physical conditions of labor in 68 departments of the 8-hour plant were examined and judged by the investigators in relation to six special factors: muscular strain, eye strain, noise, bad lighting, bad air conditions such as fumes, smoke, etc., and the prevalence of night work.[1] Results of this inquiry are summarized in Table 32 and given in detail in Table 34 at the end of the chapter. While obviously, such factors could not, for the most part, be rated by exact measurements, yet they indicate roughly the physical demands of the work. The effect on the workers of these conditions is suggested by certain objective indices in each department, that is, the relative amount of labor turnover per month, the average number of transfers asked and granted monthly through the medical department, the number of headaches reported at the hospital, and the number of days absent.

Table 31 shows that 75 per cent of the "days absent" were due to sickness. The number of headaches reported at the hospital is obviously only a rough measure of physical disability. Headaches arise from the most diverse causes, often totally disconnected with the work, such as intemperance and indigestion. That the conditions of work are, however, genuinely related to the headache rate is evident from the fact that at both plants the highest rate is reported by workers in departments where the strain upon the eye is greatest, and high rates in departments in which the predominating physical factor, such as bad lighting, may credibly induce headache.

EXPLANATION OF TABLE 32.

The various indices, such as turnover, requests for transfer, etc., were compiled from records kept at the 8-hour plant and are given in Table 32 in columns. In this summary table, the departments characterized by any one of the physical factors mentioned above are grouped together and given in the extreme left-hand column. Each column representing turnover, etc., gives the monthly average for each group of departments in percentages of the number employed and the ranking of each group by its median. In each column the average rate and the median rank for each group may be compared with the average rate and the median rank for all 65 departments given at the top of the table.

To avoid complications which might arise from the inclusion of women, this table omits the three departments employing women at the 8-hour plant, that is magneto, coil unit and clerks. The department showing the median record of all 65 departments is the thirty-third, so that whenever a department is higher or lower in rank than 33, when placed in the order of its turnover rate, or in the order of any other of the headings of the columns, it indicates that the special conditions of labor in the department have had some special effect in raising or lowering the figure. Thus of the 13 departments characterized by bad air conditions, the department showing the median record—that is, the seventh—is forty-ninth when all departments of the factory are placed in order of turnover. The higher figure suggests the effect of smoke, etc., in increasing turnover.

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[1] The investigators when rating the departments were unaware of the purpose of the ratings, so that no bias entered into their judgments.

TABLE 32.—*Summary of comparative standing of departments, measured by the percentage of monthly labor turnover, requests for transfer, transfers granted, etc.*

EIGHT-HOUR PLANT.

Departments grouped according to undesirable conditions.	Requests for transfer.	Transfers granted.	Turnover.	Headaches reported.	Daily absences.
All departments, 65:					
Average rate [1]	7.76	0.38	1.12	1.42	6.13
Position of median	33	33	33	33	33
Bad air conditions (13 departments):					
Average rate	11.73	.43	1.39	1.12	6.45
Position of median among all departments	52	48	49	33	36
Noise (5 departments):					
Average rate	10.37	.40	1.28	1.16	6.82
Position of median among all departments	42	45	42½	27½	43
Eye strain (9 departments):					
Average rate	9.13	.50	1.14	2.10	6.29
Position of median among all departments	47	49	35	48½	40
Night work (17 departments):					
Average rate	7.73	.40	1.19	1.49	5.76
Position of median among all departments	29	42	31½	33	33
Bad lighting (14 departments):					
Average rate	7.62	.41	1.04	1.95	5.52
Position of median among all departments	between 29-30	between 42-44	28½	between 44½-52	between 30-31
Muscular strain (9 departments):					
Average rate	6.79	.28	1.20	1.23	6.38
Position of median among all departments	25	30	25½	33	44½

[1] Definition of terms used in this table—Average rate: The monthly average for each group of departments in percentage of the number employed. Position of median: The median for each of the groups was found. This was ranked among all the departments.

DEPARTMENTS WITH HIGHEST RATES.

1. TURNOVER.

Taking each column separately we find turnover highest in the group of 13 departments in which the conditions of the air are worst, involving heat, smoke, fumes, gases. The average turnover in these departments is 1.39 per cent of the monthly force as contrasted with a rate of 1.12 for all departments, and the rank is forty-ninth, as compared with thirty-third for all departments. In the detailed table (Table 34 at close of chapter) a good example of this group is the foundry, No. 65, characterized by heat, smoke and fumes with a turnover almost twice as high as the average for the whole plant, 2.2 per cent against 1.13.[1] Of all 68 departments ranged in the order of turnover rate, the foundry is sixty-fifth. Similarly the drop forge department, No. 64 in the detailed table, where the heat and smoke are great, has also a turnover almost double the average, and is also bracketed sixty-fifth in order. The windshield department, too, with bad ventilation, fumes, and heat, has a turnover of 2 per cent and is sixty-third in order.

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[1] The detailed table includes all 68 departments of the factory, median position 34½, average turnover 1.13 instead of 1.12 as in the summary table.

Second to the group with bad air conditions, turnover is next highest in the five departments in which there is the greatest noise, averaging 1.28 per cent per month of the force as against a turnover of 1.12 per cent for the factory as a whole. In these departments, also, the number of men absent is the highest, 6.82 per cent of the force each month as against 6.13 for the whole factory. Requests for transfer are also next to highest, 10.37 per cent per month as against 7.76 per cent.

It is often stated that workers grow accustomed to great noise in industrial establishments and hence do not mind it. But the new workers, among whom, as will be shown later, turnover is disproportionately great, leave their jobs before they have time to become used to or adapt themselves to great noise, so that this factor tends to operate most harmfully by increasing instability among the group of workers which already tends to be most shifting.

2. REQUESTS FOR TRANSFER and TRANSFERS GRANTED.

In analyzing the columns of Table 32 representing requests for transfer and transfers granted, a significant fact is disclosed. More important even than showing the relation of working conditions to turnover, headache rate, etc., this table shows statistically the value of the transfer system as a deterrent to turnover. The workers who leave a department by transfer would without the transfer system in all likelihood have left the plant entirely. Hence the distastefulness of certain departments and kinds of work is indicated not by turnover alone but by "turnover" plus "transfers granted." It may be further gauged by the requests for transfer, since even if these requests are not all granted, the existence of the system and the possibility of favorable action on the requests undoubtedly keeps many in the factory who would otherwise leave.

It is, therefore, highly significant that in the summary table the distastefulness of work, as indicated by the order reading down the columns of "turnover" plus "transfers granted" should be identical with the indications according to the column of "requests for transfer." To this there is only one unimportant exception, the groups characterized by bad lighting and muscular strain, which are fifth and sixth in order of "requests for transfer," being sixth and fifth in order of "turnover" plus "transfers granted."

In the summary Table 32 departments are listed in the order of "requests for transfer." The most distasteful physical factors are the following, as indicated by rates above the average "requests for transfer" (7.76 per cent monthly), and above the average of "turnover" plus "transfers granted" (1.50 per cent monthly):

	Requests for transfer.	Turnover plus transfers granted.
	Per cent.	*Per cent.*
Bad air conditions	11.73	1.82
Noise	10.37	1.68
Eye strain	9.13	1.64
Night work	7.73	1.59

In the detailed table (Table 34) an interesting example of this general correlation of requests for transfer with turnover plus transfers granted is shown by department No. 6, body steel, where the requests for transfer are well below the average rate (4.4), while the granting of such requests is slightly above the average (0.40) and turnover is extremely low (0.39). In the individual departments exact correlation in each case can not be expected. In many cases men do not leave even if their desire to change is not realized, and, on the other hand, in departments which are highly distasteful, men leave in large numbers, even though the transfer rate is also high. Thus, for instance, in the windshield department, No. 63, a high percentage of requests is more than balanced by transfers, but the turnover rate is nevertheless very high.

Special causes may operate which account for the lack of correlation in individual cases. Thus another department with a very high turnover is small tools, sixty-eighth in order, and with an average of 2.89 per cent. The high turnover, which exists here in spite of a high percentage of transfers, appears to be in part due to the wages paid. It has already been noted that the high wages at this plant tend to hold the men and thus keep down the turnover. For the most part also wages are so standardized throughout the factory that no preferences are shown for special departments on the score of higher pay. But in a few departments, of which small tools is one, highly skilled men are employed at wages not higher than in other competing plants in the city. In such departments, the wage does not suffice to hold the workers.

Tested by a standard mathematical method,[1] the correlation of requests for transfer with turnover plus transfers granted is true of the detailed table also, in spite of individual variations. The value of this correlation is to show statistically how turnover may be reduced by transferring workers at their requests from unsuitable or uncongenial departments. Obviously the transfer system does not work of itself. It presupposes and involves the existence of a well-organized personnel or employment department, which is itself one of the essentials in the reduction of the labor turnover.

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[1] The Pearson method of correlation, the formula for which is $r = \frac{\Sigma\, xy}{n\sigma X\sigma y}$. The correlation is .51±.06.

An interesting example of successful transfer may be quoted from another metal-working plant where the transfer system was being introduced in a determined effort to lower the turnover rate:

"This [transfer] was something never attempted," writes Mr. J. M. Williams, in an account of the Fayette R. Plumb Co.[1] "If a man did not suit his foreman, he was fired and no questions asked.

"Now we look into unsatisfactory cases, try to find the causes, remedy them if we can, and if we can't, try to locate the unsatisfactory man in another department.

"Just a few cases of what we have done: We have one young man of undoubted ability, good personality, pleasant, and obliging. He became a regular Monday absentee, took all that was said to him as a reprimand with a lackadaisical air, and had evidently lost his 'pep.' We found upon investigation that he was fast becoming disgusted with his outlook and felt that he was up against a blank wall. We transferred him to a semiexecutive position in another department, gave him larger responsibilities and a larger salary, and he has more than made good.

"Another man was a boss trucker, who made a flat failure of the job. He was then made head inspector of one of our hardest departments and has done wonders in bringing up the general efficiency of the department. He was temperamentally unfitted for one job and fitted for the other."

3. HEADACHE RATE.

The headache rate, as has been pointed out, is highest, averaging 2.10 per cent monthly, in the group of 9 departments in which eye strain is most prevalent. Next in order, with headaches above the average for the whole factory, are the 14 departments characterized by bad lighting, average 1.95 per cent, and the 17 departments having night work, average 1.49 per cent.

LABOR TURNOVER AT THE TEN-HOUR PLANT.

At this plant there was at the time of the investigation no transfer system, no physical examination of workers before employment, no effort to select workers in any way other than by the guess of the

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[1] U. S. Bureau of Labor Statistics, Bulletin No. 227, p. 173. Proceedings of the Employment Managers Conference. Philadelphia, 1917. An Actual Account of What We Have Done to Reduce our Labor Turnover. John M. Williams, secretary of Fayette R. Plumb (Inc.); president Philadelphia Association for the Discussion of Employment Problems.

TABLE 33.—*Summary of comparative standing of departments,* [illegible] *the percentage of monthly labor turnover and headaches rep*[illegible]

TEN-HOUR PLANT.

Departments grouped according to undesirable conditions.	Men's departments.			[illegible] depart-		
	Number of departments.	Turnover, September, 1916–December, 1917.	Headaches reported, 1917.	[illegible]	[illegible]	Headaches reported, 1917.
All departments, 35:						
Average rate[1]	20	12.8	1.22	[illegible]	[illegible]	2.58
Position of median		between 19-20	between 11-12			23
Night work:						
Average rate	10	15.8	1.11	....		
Position of median among all departments.		between 28-31	between 7-8			
Muscular strain:						
Average rate	13	14.9	.94	[3] 1	....	....
Position of median among all departments.		26½	9			
Bad lighting:						
Average rate	10	14.6	1.21	3	12.3	2.[illegible]
Position of median among all departments.		between 20-26½	between 8-12		24	[illegible]
Bad air conditions:						
Average rate	7	13.8	1.44	3	10.6	[illegible]
Position of median among all departments.		26½	19		17	
Eye strain:						
Average rate	3	11.8	2.38	6	9.9	[illegible]
Position of median among all departments.		19	30		between 15-17	between 31-[illegible]
Noise:						
Average rate	8	10.6	1.45	4	12.4	2.62
Position of median among all departments.		13½	between 12-21		between 18-25	between 27-28

[1] Definition of terms used in this table—Average rate: The monthly average for each group of departments in percentage of the number employed. Position of median: The median for each of the groups was found. This was ranked among all the departments.

[2] No women employed on night work; rate of men only in mixed departments not applicable to this table.

[3] Data from one department deemed insufficient.

LABOR TURNOVER AND LENGTH OF EMPLOYMENT.

It has long been known in a general way that the labor turnover is greatest among new employees; that is, in most factories a certain proportion of "floaters" drift in and out of the plant, remaining for very short periods of employment.

In the present investigation an attempt was made to study in some detail[1] the relation between the labor turnover and the worker's length of service in the factory. From figures obtained at the 10-hour plant we are able to show the exact duration of employment of all persons leaving the factory at a given date, as compared with the length of service of the total working force then employed at the plant. The great expenses, direct and indirect, involved in the training of new employees lends special interest to the record. The facts are shown graphically in charts 36 and 37. The circle, B, representing the make-up of the entire plant on July 1, 1918, is divided into separate sectors for the different lengths of employment of the force.[1] Over half, 53.02 per cent of the total force, represented by the hatched area, had been continuously employed for more than one year. Only 27.96 per cent had been employed as short a time as three months or less; 6.24 per cent had been employed more than three but less than six months, and about the same percentages between six and nine months and between nine months and a year.

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[1] For studies of turnover in relation to length of service, see Monthly Labor Review of the U. S. Bureau of Labor Statistics, March, 1919, p. 35. Labor Turnover in Cincinnati, Emil Frankel. April, 1919, p. 23, Labor Policies and Labor Turnover in the California Oil Refining Industry, Paul F. Brissenden. P. 53. Labor Turnover in Milwaukee, Wm. F. Kirk.

The circle, A, representing the total number of persons who left the plant at approximately the same date (i. e., in the course of three weeks, centering around July 1) is likewise divided into separate sectors for the same lengths of service at the plant. The hatched area here shows that only 12.60 per cent had been employed over a year, as compared with 53.02 per cent in circle B with previous service of over one year.

In circle A, 67.95 per cent left after continuous employment of three months or less, as against only 27.96 per cent of the total force in circle B who had been employed so short a period of time.

Further particulars concerning the persons represented by these two sectors in the two circles (viz, 67.95 per cent and 27.96 per cent, respectively) are given in the detailed charts beneath the circles. These show that of all who left, 38.06 per cent quit work in the first month of employment. The largest proportion (11.56 per cent) went in their third week, the next highest proportion (10.66 per cent) in the second week. In the second month the numbers of those who left dropped to 21.58 per cent, and in the third month to 8.31 per cent of the total number leaving.

On the other hand, of the total labor force only 13.95 per cent had been employed for so short a period as one month or less, only 8.86 per cent and 5.15 per cent for such short periods as two months and three months or less, respectively.

These figures emphasize the importance of providing desirable and hygienic conditions of labor. Initial discomforts or difficulties undoubtedly add to the impulse to leave without adequate trial of a job. Even a good personnel department and care in hiring are of little avail to hold the workers if working conditions give ground for great dissatisfaction. In many regards, metal-working plants inevitably involve disagreeable surroundings of noise, heat, fumes, smoke, etc.

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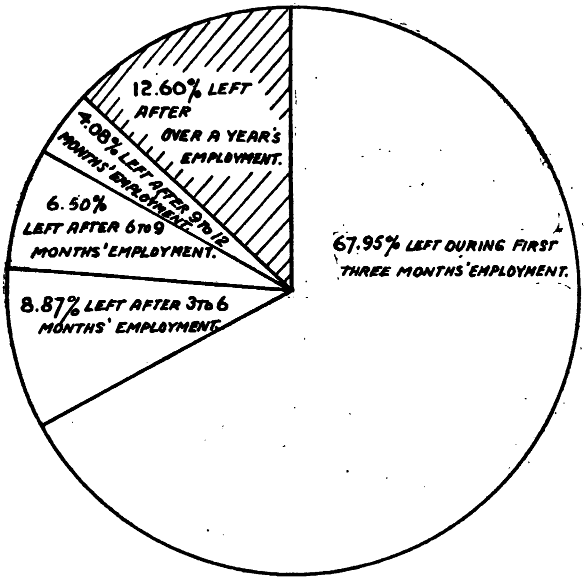
[1] A fair sample of the factory as a whole was obtained by choosing all names beginning with S, numbering roughly 1,000.

CHART 36.—*Comparative length of employment of persons leaving and of the total working force, ten-hour plant.*



A. TOTAL NUMBER OF PERSONS LEAVING JUNE 20 TO JULY 10, 1918, SUBDIVIDED ACCORDING TO LENGTH OF CONTINUOUS EMPLOYMENT AT PLANT.

DETAIL SHOWING SUBDIVISION OF ALL PERSONS LEAVING DURING FIRST THREE MONTHS OF EMPLOYMENT.

(67.95 PER CENT OF TOTAL LEAVING.)

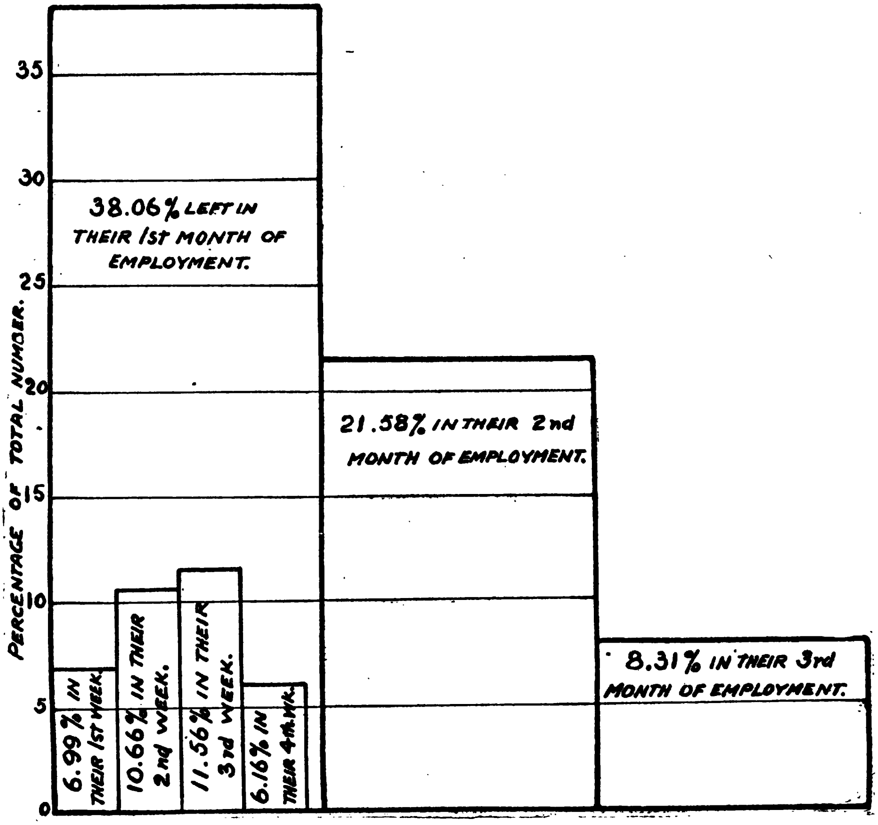
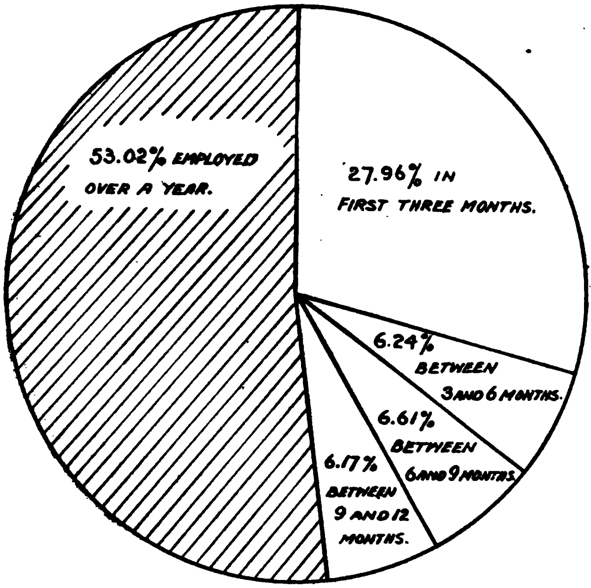


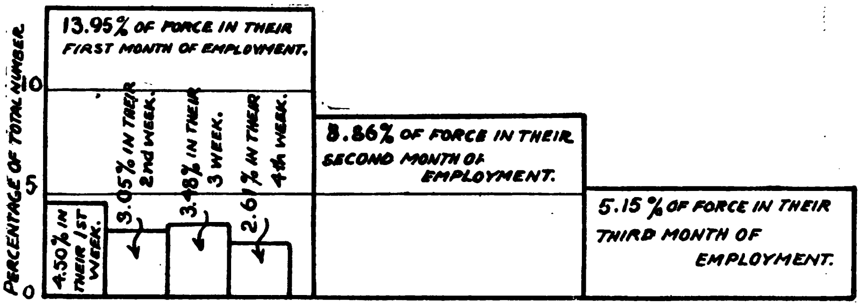
CHART 37.—*Comparative length of employment of persons leaving and of the total working force, ten-hour plant.*

B. TOTAL WORKING FORCE JULY 1, 1918, SUBDIVIDED ACCORDING TO LENGTH OF CONTINUOUS EMPLOYMENT AT PLANT.



DETAIL SHOWING SUBDIVISION OF WORKING FORCE IN FIRST THREE MONTHS OF EMPLOYMENT.

(27.96 PER CENT OF TOTAL FORCE.)



The critical question is whether these concomitant evils have been reduced so far as possible by the best technical devices and balanced by short hours and good pay; in a word, whether the management has taken cognizance of them as deterrents to efficiency and good will on the part of their workers, and hence as essential factors in the labor turnover. An interesting example of stabilizing labor by improving the conditions of employment is provided by a well-known firm in a different line of manufacture, whose employment manager writes as follows:[1]

Because the employment department has been interested to record the reason given by each departing employee for leaving its service, and to tabulate this information at intervals, it has been able to discover a number of common causes of dissatisfaction, which resulted in remedial recommendations being made, which when adopted almost immediately resulted in stopping the exodus of dissatisfied employees. * * * By reason of the steps taken by the company to remove causes that tended to make employees dissatisfied it was able to reduce these cases to such an extent that the total number recorded in 1915 represents only 17½ per cent of the total number who left in 1913 because they were dissatisfied either with their wage or their work.

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[1] Annals of the American Academy of Political and Social Science, May, 1916, p. 92. The Work of the Employment Department of Dennison Manufacturing Co., Framingham, Mass., Philip J. Reilly, employment manager.

TABLE 34.—*Comparative standing of departments, measured by the percentage of monthly labor turnover, requests for transfers, transfers granted, etc.*

EIGHT-HOUR PLANT.

Department No.	Department name.	Average number men in department.	November, 1916, to August, 1917.[1]						Headaches reported September–October, 1917.		Men absent daily, April, 1917.		Distasteful conditions: Eye or muscle strains; bad air or lighting; noise; night work.[2]
			Turnover.		Requests for transfer (medical department).		Transfers granted (medical department).						
			Order.	Rate	Order.	Rate	Order.	Rate	Order.	Rate	Order.	Rate	
	Average of all departments	......	34½	1.13	34½	7.77	34½	0.38	34½	1.45	34½	6.11	
1	Body builders	115	1st	0.00	23d	4.9	36½	0.35	19th	0.71	46th	6.71	e, m, n.
2	Tinsmiths	143	2d	.31	22d	4.6	5th	.09	33d	1.10	65th	10.58	N, A.
3	Differential cases	470	3d	.32	4½	.7	23d	.25	52d	2.05	47th	6.81	e, m, n, a, l.
4	Heat treatment	1,033	4½	.38	58th	12.5	39½	.37	33d	1.10	36th	5.97	E, M, A, NW.
5	Transmission covers	388	4½	.38	62d	15.0	46½	.42	40th	1.37	12th	3.94	n, a.
6	Body steel	313	6th	.39	21st	4.4	44th	.40	62d	3.29	27th	5.47	e, L, NW.
7	Factory service	216	7th	.49	26th	5.6	68th	1.35	4½	0.00	7½	3.35	NW.
8	Drive shaft	501	8th	.51	45th	9.4	46½	.42	58½	2.90	32d	5.71	m, L.
9	Maintenance B	138	9th	.53	17th	3.5	11th	.13	63d	3.30	44½	6.62	e, M, n, NW
10	Maintenance E	187	10½	.54	8½	1.9	60th	.65	18th	.70	7½	3.35	M, n, l, NW.
11	Triple gears	276	10½	.54	2½	.5	1st	.00	54th	2.40	34½	5.86	M, L.
12	Rear axle housing	797	12th	.58	63½	15.3	56th	.58	43d	1.50	34½	5.86	m, n, l.
13	Crank-shaft	776	13th	.68	37th	8.4	31st	.31	37th	1.29	3d	2.49	e, m, n, a, l, nw.
14	Gears	578	14th	.70	59th	12.7	63d	.79	44½	1.60	24th	5.32	m, L.
15	Cylinder	553	15th	.72	11th	2.4	59th	.64	41½	1.40	37th	5.98	e, m, a.
16	Carpenters	79	16th	.73	36th	8.2	21st	.24	4½	.00	68th	18.01	m.
17	Paint shop	195	17th	.82	31½	7.5	51st	.49	27½	1.00	16½	4.61	A, L, NW.
18	Transmission bullards	203	18th	.83	7th	1.6	42d	.38	30th	1.05	48th	6.85	m, n, nw.
19	Students	98	19th	.84	4½	.7	9th	.11	21½	.80	67th	12.89	nw.
20	Repair and test	110	20th	.85	10th	2.2	7th	.10	25th	.9	57th	7.57	a, l.
21	Bow department	577	21st	.86	6th	1.0	19th	.23	66th	3.90	21st	5.03	E.
22	Tool stock	566	22d	.88	20th	4.1	10th	.12	16th	.56	13th	4.25	
23	Tool grinding	266	23d	.93	65th	15.6	67th	1.18	60th	2.98	51st	7.08	E, a, L.
24	Loading dock	742	24th	.95	35th	8.1	52d	.50	23d	.87	42d	6.53	m, n, a, l.
25	Pressed steel	451	25½	.97	54th	11.5	27½	.28	47th	1.76	59th	7.85	
26	Shipping room	207	25½	.97	15th	3.0	30th	.30	44½	1.60	60th	7.86	M.
27	Fender	646	28½	.99	34th	8.0	17th	.20	41½	1.40	2d	2.38	e, m, n, a.
28	Pressed steel No. 2	239	28½	.99	19th	3.8	15th	.18	68th	4.49	10th	3.50	e, m, L, NW.
29	Rough stock	232	28½	.99	33d	7.8	34½	.34	27½	1.00	22d	5.04	e, m, n, nw.
30	Tool repair	297	28½	.99	47th	9.7	50th	.48	48½	1.80	40th	6.43	n, E, m, NW.
31	Millwrights	553	31½	1.00	25th	5.4	7th	.10	13½	.52	61st	7.99	M, A, L, NW.
32	Power house	418	31½	1.00	16th	3.3	21st	.24	10th	.26	11th	3.55	n, a, NW.
33	Clerks	237	35th	1.10	8½	1.9	25th	.27	55th	2.60	1st	1.38	e.
34	Crank case	564	35th	1.10	60th	13.4	57th	.59	35½	1.20	49th	6.94	E, m, A, l.
35	Bullard machine	96	35th	1.10	1st	.3	3d	.07	4½	.00	58th	7.68	a, l, nw.
36	Radiator	887	35th	1.10	57th	12.2	33d	.33	46th	1.70	56th	7.53	A, l.
37	Stock, WXYZ	702	35th	1.10	30th	7.3	42d	.38	9th	.25	4th	2.52	L.
38	Cotton room	49	38th	1.15	43d	8.9	39½	.37	4½	.00	16½	4.61	a, nw.
39	Transmission parts	1,602	39th	1.16	53d	10.9	29th	.29	39th	1.36	38th	6.29	n.
40	Bushings	330	42½	1.20	31½	7.5	45th	.41	53d	2.35	28th	5.49	e. m, N, a, l.
41	Cyanide	225	42½	1.20	63½	15.3	58th	.61	17th	.66	33d	5.74	e, a, l, NW.

[1] Averages calculated separately on the number of employees in each department each month and averaged for the different months.

[2] Capital M and small m, respectively, for work involving muscle strain, according to degree; capital E and small e for work involving eye strain; capital N and small n for noise; capital L and small l for lighting; capital A and small a for air conditions, such as temperature, humidity, smoke, fumes, dust, and lack of ventilation; capital NW and small nw for night work, regular or occasional.

TABLE 34 (continued).—*Comparative standing of departments, measured by the percentage of monthly labor turnover, requests for transfers, transfers granted, etc.*

EIGHT-HOUR PLANT—Continued.

Department No.	Department name.	Average number men in department.	November, 1916, to August, 1917. Turnover. Order.	Rate	Requests for transfer (medical department). Order.	Rate	Transfers granted (medical department). Order.	Rate	Headaches reported September-October, 1917. Order.	Rate	Men absent daily, April, 1917. Order.	Rate	Distasteful conditions: Eye or muscle strains; bad air or lighting; noise; night work.
	Average of all departments	......	34½	1.13	34½	7.77	34½	0.38	34½	1.45	34½	6.11	
2	Springs	298	42½	1.20	51st	10.7	18th	0.21	67th	3.98	25th	5.42	e, m, n, a.
3	Steam fitters	174	42½	1.20	27th	5.8	55th	.55	4½	.00	66th	11.99	nw.
4	Steering gear	526	42½	1.20	42d	8.8	25th	.27	27½	1.00	18th	4.87	e, m, N, l.
5	Tool room	1,409	42½	1.20	13½	2.9	16th	.19	4½	.00	23d	5.11	n, a.
6	Valve pushrod	388	46th	1.30	40½	8.6	32d	.32	50½	1.90	5th	2.99	e, m, l.
47	Connecting rods	446	47th	1.34	55th	11.6	38th	.36	38th	1.30	53d	7.19	m, n, NW.
48	Front axle	906	49th	1.40	46th	9.4	21st	.24	12th	.42	9th	3.47	e, m, n, a, l.
49	Springs	156	49th	1.40	29th	6.3	53½	.52	24th	.90	31st	5.68	n, A, L, NW
50	Tool design	113	49th	1.40	13½	2.9	4th	.08	57th	2.80	50th	6.95	E.
51	Tool and die room	1,151	51st	1.46	24th	5.0	14th	.17	65th	3.50	14th	4.41	e, m, n, a, L.
52	Maintenance Y	239	52d	1.49	2½	.5	36½	.35	21½	.80	19th	4.89	m, n, l, n, w.
53	Cold heading	665	55½	1.50	38½	8.5	25th	.27	35½	1.20	26th	5.43	E, n.
54	Control shaft	129	55½	1.50	38½	8.5	13th	.15	4½	.00	20th	5.02	A, l.
55	Electrical	418	55½	1.50	18th	3.6	34½	.34	20th	.73	15th	4.49	m, a.
56	Motor	1,282	55½	1.50	61st	13.6	64½	.80	27½	1.00	43d	6.54	m, N, a, l.
57	Spark and coil	496	55½	1.50	56th	11.7	27½	.28	31st	1.07	52d	7.15	A, l, nw.
58	Transport	767	55½	1.50	49th	10.0	64½	.80	13½	.52	39th	6.36	E.
59	Top department	568	59th	1.56	40½	8.6	49th	.46	64th	3.38	41st	6.45	E, l.
60	Magneto	873	60th	1.66	50th	10.5	61st	.70	58½	2.90	62d	8.49	E, m, n, a, l.
61	Rings	177	61st	1.80	67th	17.6	62d	.77	15th	.54	6th	3.05	A.
62	Pyrometers	85	62d	1.97	48th	9.8	7th	.10	50½	1.90	64th	8.83	e, NW.
63	Windshield	261	63d	2.00	44th	9.3	53½	.52	61st	3.28	29th	5.56	e, m, A, l.
64	Drop forge	438	65th	2.20	66th	17.4	48th	.45	11th	.35	44½	6.62	e, M, N, A, NW, L.
65	Foundry	4,786	65th	2.20	52d	10.8	42d	.38	33d	1.10	30th	5.67	e, M, A, L, NW.
66	Piston	196	65th	2.20	68th	27.0	66th	.82	48½	1.80	63d	8.66	m, A, l.
67	Construction	446	67th	2.43	28th	6.1	12th	.14	4½	.00	55th	7.45	M.
68	Small tools	289	68th	2.89	12th	2.6	2d	.04	56th	2.70	54th	7.39	e, a, l, NW.

TABLE 35.—*Comparative standing of departments measured by percentage of monthly labor turnover and headaches reported.*

TEN-HOUR PLANT.

Department No.	Name of departments (in order of turnover).	Sex of workers.[1]	Number of persons in department in two intermediate months within period of study.		Turnover. Sept. 1916 to Dec. 1917.		Headaches. 1917.		Distasteful conditions: Eye or muscle strains; bad air or lighting; noise; night work.[2]
			December, 1916.	June, 1917.	Order.	Rate.	Order.	Rate.	
1	Cutting	M and W	68	64	1st	2.2	6th	0.30	
2	Tool and machine	M	701	730	2d	4.4	13th	1.10	
3	Fuse (primer house)	W	195	203	3d	4.7	35th	6.63	E.
4	Packing buttons	W	92	109	4th	5.2	14th	1.21	
5	Stock and store	M	86	70	5th	6.0	3d	.27	M, L.
6	Lacquer	M and W	107	91	6th	7.3	18th	1.59	A.
7	Fuse (powder room)	M and W	807	1,005	7½th	7.4	20th	1.74	NW.
8	Pack and ship	M	124	135	7½th	7.4	11th	.87	M.
9	Fuse (inspection)	M and W	189	297	9th	7.5	34th	6.49	E.
10	Drawing	M	105	150	10th	8.1	30th	3.13	E, N.
11	Screw	M	71	77	11th	8.4	12th	.93	N, L, A, NW.
12	Blanking	M	156	138	12th	8.5	7th	.33	N, NW.
13	Rivet	M	93	85	13½th	9.1	21st	1.77	N, L.
14	Hot forging	M	230	269	13½th	9.1	29th	2.99	L, N, A, NW.[3]
15	Fuse (tops)	M and W	873	1,000	15th	9.9	32d	3.58	E, N, L, NW.
16	Plating	M	80	75	16th	10.3	26th	2.25	M, A.
17	Solder	M and W	39	96	17th	10.8	31st	3.21	A, E.
18	Closing	M and W	126	137	18th	10.9	28th	2.95	N.
19	Buff by hand	M	72	49	19th	11.0	9th	.39	M, N, E.
20	Rolling mill	M	780	899	20th	11.7	8th	.37	M, L, NW.
21	Butt	M and W	154	134	21st	12.4	24th	1.91	
22	Yard	M	1,260	1,573	22d	12.7	10th	.73	M.
23	Foot press	W	134	137	23d	13.3	22d	1.82	E.
24	Fastener	W	184	169	24th	13.4	16th	1.43	E, L.
25	Press	W	114	131	25th	13.7	27th	2.48	A, L, N.
26	Brass finish (by hand)	M and W	86	183	26½th	14.5	23d	1.85	M, NW.
27	Dip	M	79	64	26½th	14.5	19th	1.60	A, L, M.
28	Brass finish (automatics)	M	63	56	28th	14.8	25th	2.00	A, N, NW.
29	Truckers	M	49	64	29½th	14.9	15th	1.25	M.
30	Trim and knurl	M. and W	58	75	29½th	14.9	17th	1.45	N.
31	Wire mill	M	188	199	31st	15.5	1st	.09	M, N, A, L, NW.
32	Fuse (body)	M	698	757	32d	16.2	33d	3.63	M, L, E, NW.
33	Casting	M	741	839	33d	18.3	4th	.28	M, NW.[4]
34	Steam	M	79	108	34th	23.8	2d	.19	L, A, M, NW.
35	Rivet trucker	M	74	91	35th	31.5	5th	.29	L, M, NW.
	Average of all departments (35).				18th	11.6	18th	1.80	
	Average of men's departments (20).				19½th	12.8	11½th	1.22	
	Average of women's and mixed departments (15).				17th	9.9	23d	2.58	

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[1] Department is labeled M. or W. according as men or women are in a majority of two-thirds or more; departments in which the proportion of one sex to the other is less than two-thirds are labeled M. and W.

[2] Capital M and small m, respectively, for work involving muscle strain, according to degree; capital E and small e for work involving eye strain; capital N and small n for noise; capital L and small l for lighting; capital A and small a for air conditions such as temperature, humidity, smoke, fumes, dust, and lack of ventilation; capital NW and small nw for night work, regular or occasional.

[3] Three eight-hour shifts.

[4] Men leave when tasks completed.

NOTE ON METHOD OF CALCULATING LABOR TURNOVER.

In this investigation the definition and method of calculating labor turnover adopted by the National Conference of Employment Managers, June, 1918, has not been followed. According to this definition percentage of labor turnover in any given period is the ratio of the total number of separations to the average number of employees during that period.[1] But this method of calculating turnover does not allow for factories which are reducing their labor force, as well as for those which are expanding.

When many men are deliberately dismissed on account of the state of the market, as was the case at the 8-hour plant in the year under consideration, this reduction should plainly not count as an indication of high turnover. The definition of the National Conference of Employment Managers attempts to meet this difficulty by recommending that "in case the number employed by a plant or a department of a plant decreases because it is the deliberate policy of the plant management to reduce permanently its working force, this fact should be explicitly stated and the reasons for the reduction in force given."

But such a statement does not give any numerical measure of the correction required for statistical purposes. Hence in this investigation a measure of turnover held to be better has been adopted by using for the numerator of the ratio not the total number leaving but the number of persons leaving in any given period *who are replaced.* The turnover rate is then the proportion of such changes to the average number employed.

It is only when the number of newly hired workers is greater than the number leaving that the turnover is equivalent to the actual number leaving; when more men leave than are hired, the larger number is not replaced. Turnover may, therefore, be calculated by taking the lesser of these two numbers, representing those hired and those leaving.[2]

A good example may be quoted from Florence, to whose manual the reader is referred for a fuller discussion of methods of calculating turnover. He suggests that during a month of four weeks, in the—

First week	10 men leave and	13 men are hired, replacement	10
Second week	15 men leave and	11 men are hired, replacement	11
Third week	12 men leave and	17 men are hired, replacement	12
Fourth week	8 men leave and	8 men are hired, replacement	8
	45	49	41

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[1] U. S. Bureau of Labor Statistics, Monthly Review, June, 1918, p. 172.

[2] For an opinion differing from this view, see The Turnover of Factory Labor, Sumner H. Schlichter, Appleton, New York, 1919. For an opinion confirming this view, see Handbook on Employment Management in the Ship Yard; Special Bulletin Labor Loss, Industrial Relations Division, United States Shipping Board Emergency Fleet Corporation, Philadelphia, 1918.

Thus the total replacements of the four weeks during the month are 41, but if all who had left and all who were hired during the month as a whole are added the lesser of the two figures is found to be 45.[1]

These figures show also that weekly rates of turnover can not be merely added to obtain monthly rates; nor can monthly rates be added to obtain yearly rates, because in adding up the turnover figures for the shorter periods of time, the more frequently calculated difference between the numbers hired and the numbers leaving lowers the final figures.

The method of calculating turnover used by Alexander in his study of 12 metal plants is to base the rate not on the total number employed but on the actual net increase in numbers. He states, for instance, as given in our text, page 155, that 42,751 persons were engaged during the year "in order to increase the working force by only 6,697. In other words, about six and one-third times as many people had to be engaged during the year as constituted the permanent increase of the force at the end of that period."

In this way allowance is made for factories which are increasing their labor force at different rates. When the labor force is being decreased, it is possible (though not specifically stated by Alexander) to arrive at a similar measure of the turnover by comparing the total number leaving to the total decrease of the force. We have accordingly used this measure adopted by Alexander, as well as the method given above, and have stated for both factories the amount of the turnover in relation to the average employed, and the ratio of the number hired or leaving to the net increase or decrease in numbers, during a given period.[2]

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[1] Use of Factory Statistics in the Investigation of Industrial Fatigue. A Manual for Field Research. Philip Sargant Florence. Columbia University Studies in History, etc., Longmans, Green & Co., New York, 1918.

[2] For 8-hour plant, p. 157; for 10-hour plant, pp. 131, 164.

CHAPTER 8.

THE EFFECTS OF REST.

1. RECESSES.

(1) Effect on Total Daily Production.

Varying results follow the introduction of 10-minute recesses in the middle of the morning and afternoon spells. With some workers the loss of time is not made good and output falls; with others the acceleration due to the recess exactly balances the interruption and output remains the same. In 12 out of 16 operations studied there was an average increase of production after the introduction of recesses. In operations having two periods of trial the gain in the second period was on the average five times greater than in the first.

(2) Effect on Hourly Rate of Production.

Recesses usually lead to a rise in the rate of production in the hours immediately following, as compared with the hours immediately preceding, the recess.

2. HOLIDAYS.

Holidays cause an increase in output.

1. RECESSES.

The introduction of recess periods in industrial work is still experimental, and opinion is still divided as to their effects. To some employers they appear wholly beneficial, to others negligible or even injurious. Even the workers themselves, chiefly through fear of losing piece rates, are sometimes opposed to their introduction. Undoubtedly the immediate effect of recesses on output is not the only criterion of their value; their general benefit in contributing to the comfort and good will of employees has been emphasized in recent publications.[1]

Yet a legitimate interest attaches to the actual effect on production of these short intervals of rest. Does the interruption of work lead to a fall of output? Does it enable output to be maintained? Does it do more?

In the Public Health Service investigation an attempt was made to obtain exact information on these points, to learn and record the actual effects of a 10-minute break in the morning and afternoon. The inquiry was a difficult one, complicated by the prejudices of both foreman and workers. Fear of losing time and wages, the common dislike of innovations, had to be overcome. In one department the antagonism to the experiment was so great that it had to be abandoned, although two weeks of trial were successful and promised further gains. Moreover, much difficulty was found in keeping under observation for a sufficient length of time the performances of the same persons before and after the introduction of recesses.

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[1] Health of Munition Workers Committee. Final report, 1918. Pages 161-162.

The investigation covered two points: first, the effect of recesses upon the total output per day; second, the effect upon the hourly rates of output during the day. While the point of immediate practical concern is obviously the effect of the break on the whole day's production, yet in any study of working capacity the change in hourly rates of output before and after recess periods is of genuine scientific interest.

The series of experiments at the 8-hour plant were more or less indeterminate, owing to various reasons which will be considered later. Experiments at the 10-hour plant, in some cases confirmed by later periods of observation, yielded fuller conclusions, and will be described here first.

RECESSES IN THE TEN-HOUR PLANT.

EFFECT ON TOTAL DAY'S OUTPUT.

At the suggestion of the Public Health Service recess periods were introduced into five departments of the 10-hour plant at various dates between February and June, 1918, viz, in charging buttons, in two soldering departments, in buffing, and in the laboratory of the factory. They were 10 minutes long, and were generally placed at about 10 o'clock in the morning and about 4 o'clock in the afternoon.

To any observer, the outward reaction of the workers to these short rest intervals is striking. To take a specific instance: in one of the solder rooms, where the employees are mostly women, as the machinery stops, or as hand tools are laid down, the whole room appears to take a deep breath; talk and laughter break out; there is general movement, running to get drinks of water, reading of newspapers by the older women, sometimes dancing by the younger; there is, in a word, genuine relaxation.

In other establishments regular provision for recreation, exercise, and ventilation have been found desirable and have been welcomed by the workers. To test the full value of recess intervals such provisions need much more careful thought than has yet been given them. The proper length of the break is also a subject for further study. Doubtless it should be regulated by the type of operation engaged in. In processes requiring dexterity, for instance, in which practice must to some extent at least be newly acquired after any material interruption of work, it is possible that shorter and more frequent breaks afford more relief from strain with less loss of practice than a single recess in the middle of the work period.

In discussing the total output for the day it is important to bear in mind that the figures are uncorrected; that is, have not been compensated for the time lost; hence if output is merely maintained, even if it does not increase after recesses are introduced, the loss of 20 minutes' working time has been made good by the workers.

Variability in the workers' responses to these short pauses for rest is well illustrated in the operation of charging buttons of various sizes. The operation of charging or applying a solder mixture on the backs of army buttons is a monotonous operation requiring dexterity and a delicate touch. The solderer holds in her right hand her stylus or brush, in her left a small wire screen tray covered with metal button backs. Before her stands a small bowl of solder mixture. She dips in the brush and applies it quickly to each of the button backs lying on the wire tray, to solder together the shank and back of the button.

Observations were made of women charging small buttons for a period of two weeks without recesses and then for two separate periods of four weeks each with recesses (Table 36). Of the 14 workers studied, five fell off in output when recesses were introduced while nine made increases ranging from 1.2 per cent to 7.6 per cent. Nine of the same 14 workers were tried in a second month of experiment, and of these three lost in output, one remained stationary, but five showed gains ranging from a fraction to over 16 per cent. In this operation, therefore, about one-third of the workers lost and about two-thirds gained in the first month with recesses; in the second month the proportions were about equal, but the gains in pounds of buttons so far outweighed the losses that the average increase per worker was 3.26 per cent.

That these increases in output are not to be ascribed merely to increased practice and experience in the course of work is indicated by the second column in Table 36 showing for each worker the date of starting the job in which he or she was engaged during the period with recesses. The 14 women soldering small buttons had all been employed at this job over four months before the introduction of the recesses, a period of time sufficiently long to have made them skilled in the work. They had all reached the stage of being paid piece rates after a preliminary period of trial on time wages.

TABLE 36.—*Effect of recess periods on total daily output, ten-hour plant.*[1]

CHARGING SMALL BUTTONS.

Check No. of worker.	Date of starting job.	No recesses.		First recess period.			Second recess period.		
		Number of observations.	Average pounds per day.	Number of observations.	Average pounds per day.	Per cent change.	Number of observations.	Average pounds per day.	Per cent change.
		Mar. 4-15.		Mar. 18-Apr. 19.			Apr. 23-May 24.		
847	Oct. 12, 1917	8	25.672	17	27.611	7.5	18	27.926	8.8
912	Oct. 1, 1917	8	27.572	18	29.457	6.7	14	29.477	6.9
839	do.	8	24.576	19	23.987	− 2.4	15	24.686	.4
846	Oct. 12, 1917	8	23.016	18	24.097	4.7	21	26.164	13.6
848	Oct. 2, 1917	8	25.817	7	27.119	5.0	......	......	......
866	Oct. 12, 1917	6	21.224	19	21.632	1.9	7	21.224	......
849	Oct. 2, 1917	8	27.652	8	28.142	1.7	......	......	......
901	Oct. 29, 1917	7	20.745	19	22.326	7.6	5	19.957	− 3.8
868	Oct. 12, 1917	8	23.224	18	24.462	5.2	21	26.969	16.1
916	Nov. 13, 1917	7	21.099	13	20.868	− 1.1	10	19.211	− 9.0
910	Nov. 7, 1917	7	25.221	11	24.536	− 2.8	......	......	......
898	Oct. 29, 1917	7	18.717	10	17.347	− 7.3	......	......	......
900	Oct. 30, 1917	8	24.803	19	24.711	− 0.4	19	23.919	− 3.6
913	Nov. 9, 1917	7	25.231	8	25.538	1.2	......	......	......
Average per worker per day						+1.96	......		+3.26

CHARGING MEDIUM BUTTONS.

		Mar. 4-15.		Mar. 18-Apr. 12.					
918	Nov. 14, 1917	4	35.716	4	38.379	7.3	(4)	(4)	(4)
826	Jan. 16, 1918	6	39.341	6	42.305	7.6			
816	Nov. 20, 1917	5	55.077	5	[2]60.733	10.2			
871	Oct. 15, 1917	6	55.849	6	[2]60.674	8.7			
882	Oct. 22, 1917	8	42.641	7	40.653	− 4.6			
879	Oct. 17, 1917	8	56.345	7	55.553	− 1.2			
815	Oct. 10, 1917	8	[3]60.196	9	[3]60.218	.4			
Average per worker per day						+ 4.1			

CHARGING LARGE BUTTONS.

		Mar. 4-15.		Mar. 18-Apr. 24.			May 20-28.		
862	Oct. 9, 1917	9	83.126	17	81.197	− 2.4	7	81.826	− 1.6
883	Sept. 27, 1917	9	48.844	15	47.994	− 1.9	5	49.863	2.1
926	Nov. 20, 1917	9	51.107	11	50.305	− 1.6	6	52.825	3.3
817	Jan. 2, 1918	7	62.171	......	......	......	6	77.383	24.4
921	Nov. 16, 1917	5	54.852	12	50.665	− 7.6	......	......	......
920	do	7	67.568	10	59.228	−12.4	......	......	......
927	Nov. 20, 1917	8	67.624	16	66.309	− 1.9	......	......	......
Average per worker per day						− 4.6	......		+ 7.1

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[1] All recesses studied at this plant fell within the months February-July, 1918.
[2] Leaves factory at 5.30 p. m.
[3] Leaves factory at 11.45 a. m. and 5.45 p. m.
[4] No more orders executed.

Again, in performing the same operation with large buttons, of six workers observed before recess periods were introduced, each one lost in output during the first month with recesses, the loss ranging from 1.6 to 12.4 per cent (Table 36). This marked decline did not, however, persist. Three of the same workers had a second period of experiment a month later, and during this time only one continued to lose, the other two making gains of 4 and 5 per cent. A fourth worker, having her first experience of recesses in this final period of observation, showed the surprising gain of 24.4 per cent over her output without recesses. This worker, No. 817, had, it is true, been employed about a month less than any of the other women before recesses were introduced in this department, so that her extraordinary rise may have been in part due to the factor of learning. Yet she had had two months at the job before the control period without recesses, and must therefore have been reasonably proficient.

A still better showing was made by three workers in another soldering operation (known as solder cap and bushing, Table 36, continued) who steadily improved their output, the increase averaging 7 per cent per worker in the first period with recesses and over 18 per cent in the second. These three workers had been employed at soldering respectively, 10, 13, and 26 years before the introduction of recesses.

Finally, great gains were made by six workers, all experienced, on still another soldering operation (known as solder body and collar), who were studied during three recess periods, covering from two to three weeks each. The output of three of these workers declined from 1 to 7 per cent during the first period. One of them continued to lose during the two subsequent periods of observation. The other two not only made good their loss, but increased their output in the second experiment by 15 per cent and 20 per cent, respectively. In the last period they showed a total increase over the time without recesses of 14 and 29 per cent. The three remaining workers had steadily increased their production during the three periods with recesses, ranging in the end from 18 to 28 per cent. The cumulative benefit was best shown by a worker whose output improved 16 per cent in the first period, 50 per cent in the second period, and 76 per cent in the last. The increase of output averaged per worker about 26 per cent.

TABLE 36 (continued).—*Effect of recess periods on total daily output, ten-hour plant.*

SOLDER BODY AND COLLAR OF THONG CASE.

Check No. of worker.	Date of starting job.	No recesses.		First recess period.			Second recess period.			Third recess period.		
		Number of observations.	Average daily output.	Number of observations.	Average daily output.	Per cent change.	Number of observations.	Average daily output.	Per cent change.	Number of observations.	Average daily output.	Per cent change.
		Jan. 28–Feb. 5.		Feb. 6–22.			Mar. 6–26.			Mar. 28–Apr. 17.		
782	Oct. 16,1917	7	1,125	6	1,308	16.0	8	1,688	50.0	4	1,982	76.0
656	June 15,1917	6	1,469	8	1,455	− 1.0	9	1,437	− 2.2	7	1,331	− 9.4
634	Nov. 5,1917	7	1,475	9	1,594	8.0	9	1,649	11.8	8	1,748	18.0
657	Dec. 19,1917[1]	6	1,729	8	1,690	− 2.3	11	2,026	17.0	7	2,236	29.0
666	Jan. 21,1918[1]	7	1,739	8	1,832	5.4	9	2,058	18.0	9	2,222	28.0
650	Nov. 23,1917	4	1,794	7	1,667	− 7.1	10	1,933	7.7	8	2,053	14.0
Average per worker						+ 3.1	...	......	+17.1	...	......	+25.9

SOLDER CAP AND BUSHING.

Check No. of worker.	Date of starting job.	No recesses.		First recess period.			Second recess period.			Third recess period.		
		Jan. 14–Feb. 5.		Feb. 6–Feb. 19.			May 15–June 6.					
754	1892	5	5,039	6	5,271	4.6	14	5,866	16.0	...	......	......
761	1905	5	4,482	6	4,876	8.7	8	5,478	22.0	...	......	......
651	Sept. —, 1908.	10	5,589	8	6,024	7.7	14	6,543	17.0	...	......	......
Average per worker						+ 7.0	...	......	+18.3	...	......	......

SOLDER STUD, SHELL AND SCREW.

Check No. of worker.	Date of starting job.	No recesses.		First recess period.			Second recess period.			Third recess period.		
		Dec. 17–Jan. 24.		Feb. 15–Mar. 12.								
754	1892	16	3,511	16	3,231	− 8.0	...	......	......	...	......	......
761	1905	13	3,373	4	2,872	−15.0	...	......	......	...	......	......
Average per worker						−11.5	...	......	......	...	......	......

SOLDER SEAM.

Check No. of worker.	Date of starting job.	No recesses.		First recess period.			Second recess period.			Third recess period.		
		Dec. 17–Feb. 1.		Feb. 8–Mar. 1.								
780	1905	4	2,721	5	2,973	9.0	...	......	......	...	......	......
791	Mar. —, 1916.	5	1,993	5	2,387	19.7	...	......	......	...	......	......
Average per worker						+14.4	...	......	......	...	......	......

SOLDER BODY, TOP AND BUSHING.

Check No. of worker.	Date of starting job.	No recesses.		First recess period.			Second recess period.			Third recess period.		
		Dec. 18–Feb. 5.		Feb. 6–Feb. 27.								
780	1905	11	2,200	5	2,448	11.0	...	......	......	...	......	......
791	Mar. —, 1916.	7	1,387	3	2,300	[2] 65.0	...	......	......	...	......	......

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[1] Previously soldered in other departments of factory.

[2] 791 has insufficient number of observations after recess to base conclusions upon.

Less striking but positive benefits from the establishment of recesses were experienced after a very short trial in the men's buffing room (Table 36, concluded). The experiment was continued only 10 days; yet of 16 men engaged in different buffing operations, only three suffered any loss of output. Production was not only maintained, but improved by all the others, showing gains which ranged from a fractional increase to 5.7 per cent over the period without recesses. This result was the more significant in view of the antagonism to the recesses on the part of the workers, who feared curtailment of piece rates, loss of practice, etc. The experiment succeeded in spite of their opposition.

Table 36 (concluded).—*Effect of recess periods on total daily output, ten-hour plant.*

COLORING RAZOR FRAMES (BUFFING).

Check No. of worker.	Date of starting job.	No recesses, Apr. 29–May 17.		With recesses, May 21–31.		
		Number of observations.	Average daily output.	Number of observations.	Average daily output.	Per cent change.
331	June —, 1913	15	2,280	8	2,299	0.8
346	Apr. —, 1910	15	2,293	8	2,331	1.7
264	June —, 1911	6	2,621	3	2,508	−4.3
230	July —, 1912	15	2,266	5	2,380	5.0
254	Sept. —, 1908	12	2,327	6	2,356	1.1
Average per worker						+0.86
BUFFING RAZOR BOXES.						
235	Mar. 3, 1918[1]	11	3,416	6	3,474	1.8
237	Mar. 16, 1918[1]	10	3,492	8	3,538	1.2
240	Mar. 19, 1918[1]	8	3,057	8	3,228	5.7
259	Sept. 12, 1917	8	6,706	6	6,652	− 0.7
269	June —, 1907	9	6,737	8	6,695	− 0.5
291	July —, 1905	11	6,749	8	6,783	0.6
276	Oct. 5, 1917	11	3,194	8	3,215	0.7
294	May —, 1904	10	3,421	7	3,434	0.3
Average per worker						+1.1
COLORING RAZOR BOXES (BUFFING).						
231	June 19, 1917	11	5,099	7	5,166	1.3
238	Mar. 3, 1918[1]	9	5,156	4	5,213	1.1
268	Sept. 28, 1917	9	5,171	7	5,221	1.0
Average per worker						+1.1
WEIGHING BRASS SAMPLES.						
		May 29–June 21.		June 24–July 15.		
27627	Apr. 1, 1918	12	240.8	10	258.8	7.5
27620	Mar. 27, 1918	8	200.1	8	229.9	14.9
27614	Mar. 14, 1918	8	296.1	5	299.8	1.2
Average per worker						+7.9

[1] Worked for at least a year previously at buffing and coloring operations in other plants.

SUMMARY OF GAINS.

In all, recess periods were introduced in 12 different operations of the 10-hour plant. In 11 of these the average daily output per worker increased after the recesses were put into effect. That the improvement was continuous and showed cumulative benefits is proved by the fact that in the four operations which had two periods of trial the gain in the second period was, on the average, five times greater than in the first; the increase in output, which averaged about 2 per cent in the first period, averaged over 11 per cent in the second.

EFFECT ON HOURLY RATE OF OUTPUT.

To compare, now, the rate of output of the two hours following the recess with the rate of the three hours preceding it, the ratios given in Table 37 are a convenient guide. In this table it should be noticed that where recess periods were introduced, the hour's output has been uniformly corrected to allow for the 10-minute loss. Thus the rate of work is shown, not the actual production. And since this is a comparison of different hours in the day, a changing group of workers may be studied, so long as they do not change during the course of the day.

In four of the six operations studied (Table 37), the afternoon recess was followed by a rise in the ratio of production, ranging from 0.9 in charging medium buttons to 10.3 in the second period of trial in charging large buttons. In only two processes did the recess increase the morning ratio. Again, in four of the six operations there was a rise in the ratio comparing the rate of the afternoon spell with that of the morning, under the recess system. Thus, for instance, in charging small buttons when there was no recess the ratio of output of the fourth and fifth hour to the first, second, and third hour was as 97 to 100. As soon as a recess was introduced after the third hour, the ratio increased to 99.3 in the first period of observation and to 102.8 in the second period. Similarly, in the afternoon, the increase was from 93.9 to 96.8 and 98.7 in the two periods of experiment. The ratio comparing the rate of the afternoon and the morning spell rose from 93.5 without recesses to 97.5 with recesses.

A slight though steady rate of increase was observable in each operation having two or three periods of experiment, and the gain or loss persisted in all periods. In solder body and collar of thong case, the process showing largest increase in total daily output, there was loss, not gain, in the ratio in the mornings of all three periods with recesses. Obviously, then, these solderers were not making a conscious spurt to increase output. Their reaction to the recesses appears to have been an involuntary one, the benefit not making itself felt until afternoon.

TABLE 37.—*Effect of recess periods on*

	Number of observations.	Period of study.	Average output observed each working hour.		
			First.	Second.	Third.
CHARGING SMALL BUTTONS.[1]					
Without recesses	105	Mar. 4 Mar. 15	2.464	2.601	2.613
Recesses:					
First period	208	Mar. 18 Apr. 19	2.508	2.604	2.588
Second period	130	Apr. 23 May 24	2.501	2.716	2.728
Difference in ratio due to recesses:					
First period					
Second period					
CHARGING MEDIUM BUTTONS.[1]					
Without recesses	32	Mar. 4 Mar. 15	4.563	4.676	4.924
Recesses	29	Mar. 18 Apr. 12	5.218	4.781	4.758
Difference in ratio due to recesses					
CHARGING LARGE BUTTONS.[1]					
Without recesses	47	Mar. 4 Mar. 15	6.392	6.587	6.752
Recesses:					
First period	81	Apr. 24 May 20	6.257	6.566	6.604
Second period	24	May 28	6.575	6.803	7.096
Difference in ratio due to recesses:					
First period					
Second period					
COLORING RAZOR FRAMES (BUFFING).					
Without recesses	76	Apr. 29 May 17	209	229	237
Recesses	30	May 31	231	252	[2] 250❙
Difference in ratio due to recesses					
SOLDER BODY AND COLLAR OF THONG CASE.					
Without recesses	51	Jan. 28 Feb. 5	135	152	151
Recesses:					
First period	62	Feb. 6 Feb. 22	137	172	[2] 170❙
Second period	56	Mar. 6 Mar. 26	176	186	[2] 202❙
Third period	43	Mar. 28 Apr. 17	179	194	[2] 211❙
Difference in ratio due to recesses:					
First period					
Second period					
Third period					

[1] Output given in pounds.

[2] Output corrected for recess period. The mark ❙ indicates the position of the recess, which is placed either at the beginning or at the end of the hour.

hourly rate of output, ten-hour plant.

CHARGING SMALL BUTTONS.[1]

Average output observed each working hour.							Ratios between hours.		
Fourth.	Fifth.	Sixth.	Seventh.	Eighth.	Ninth.	Tenth.	$\frac{\text{4 and 5}}{\text{1–3}}$	$\frac{\text{9 and 10}}{\text{6–8}}$	$\frac{\text{6–10}}{\text{1–5}}$
2.542	2.437	2.461	2.475	2.341	2.522	2.033	97.0	93.9	93.5
▌[2] 2.681	2.423	2.580	2.532	2.480	▌[2] 2.681	2.218	99.3	96.8	97.5
▌[2] 2.790	2.660	2.567	2.701	2.608	▌[2] 2.773	2.418	102.8	98.7	97.5
....	....	....	....	....	....	....	+2.3	+2.9	+4.0
....	....	....	....	....	....	....	+5.8	+4.8	+4.0

CHARGING MEDIUM BUTTONS.[1]

4.758	4.649	4.580	4.421	4.503	4.491	3.701	99.7	91.0	92.1
▌[2] 5.073	4.542	4.456	4.612	5.117	▌[2] 4.779	3.917	97.8	91.9	94.0
....	....	....	....	....	....	....	—1.9	+0.9	+1.9

CHARGING LARGE BUTTONS.[1]

6.589	6.065	6.181	6.356	6.045	6.218	5.258	96.3	92.7	92.9
▌[2] 6.571	6.172	6.108	6.344	6.367	▌[2] 6.434	5.411	98.5	94.5	95.5
▌[2] 7.248	6.884	6.697	6.850	7.026	▌[2] 7.692	6.441	103.7	103.0	100.2
....	....	....	....	....	....	....	+2.2	+ 1.8	+2.6
....	....	....	....	....	....	....	+7.4	+10.3	+7.3

COLORING RAZOR FRAMES (BUFFING).

243	238	229	242	242	239	211	107.0	94.6	100.6
247	246	254	252	252	▌[2] 238	202	100.9	87.0	97.7
....	....	....	....	....	....	....	—6.1	—7.6	—2.9

SOLDER BODY AND COLLAR OF THONG CASE.

163	159	146	153	151	148	124	110.2	90.7	95.2
164	161	151	162	[2] 162▌	158	146	101.7	96.0	97.1
192	196	183	181	[2] 193▌	185	182	103.1	98.7	97.0
203	213	196	195	[2] 216▌	201	202	107.1	99.6	101.0
....	....	....	....	....	....	....	—8.5	+5.3	+1.9
....	....	....	....	....	....	....	—7.1	+8.0	+1.8
....	....	....	....	....	....	....	—3.1	+8.9	+5.8

TABLE 37 (continued).—*Effect of recess*

WEIGHING BRASS SAMPLES.

	Number of observations.	Period of study.	Average output observed each working hour.		
			First.	Second.	Third.
Without recesses	[1] 29	May 29 June 19		25.4	29.0
Recesses	[1] 37	June 24 July 26		29.8	31.5
Difference in ratio due to recesses					

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[1] Same three experienced workers observed with and without recesses. Each was at least 7 days under observation.

periods on hourly rate of output, ten-hour plant.

WEIGHING BRASS SAMPLES.

Average output observed each working hour.							Ratios between hours.		
Fourth.	Fifth.	Sixth.	Seventh.	Eighth.	Ninth.	Tenth.	$\frac{5}{2, 3, 4}$	$\frac{9 \text{ and } 10}{6, 7, 8}$	$\frac{6\text{–}10}{1\text{–}5}$
29.2	26.9	27.8	28.5	27.6	28.2	23.8	96	93	99
[a]32.3│	29.3	29.5	31.0	[a]31.6│	28.6	26.6	94	90	96
....	....	....	....	....	....	....	—2	—3	—3

[a] Output corrected for recess period. The mark | indicates the position of the recess, which is placed at the beginning or at the end of the hour.

RECESSES IN THE EIGHT-HOUR PLANT.

EFFECT ON HOURLY RATE OF OUTPUT.

Recess periods of 10 minutes each were introduced into three departments of the 8-hour plant—rear axle housing, axle grinding, and crank case grinding—on October 15, 1917, and continued for several months. On November 5 recesses were introduced in the crank shaft grinding department, while in the commutator loom operation experiments were tried at one time with 5-minute and at another time with 10-minute periods. In some cases one recess only was introduced; in other cases two recesses for each day. The rule was to have one recess in the middle of each spell, except when the spell was so short that a recess seemed unnecessary.

Again, as in the 10-hour plant, the ratios show (Table 38) the effect of the recesses upon the rate of output in the hours following as compared with the hours preceding the break. When there was no recess in the operation of rear axle housing, evening shift, the output of the third and fourth hours compared to the first and second was as 105 to 100. When the recess period was introduced after the second hour, the ratio rose to 116 (Table 38). The change in rate of output in each spell runs from plus one in rear axle housing, morning shift, to 14 points on the evening shift in axle grinding. Only one loss in ratio was obtained, namely, in the commutator loom process, where the recess period was only five minutes long.

As explained above, in considering hourly rates of output, the hour in which the recess takes place has been corrected; that is, compensated for time lost, to show the rate of production, not the actual output. But even if the actual uncorrected output of the spell be counted, it can be shown that the effect of the recess in accelerating production just about balances the time lost by the recess. The average difference in the ratios between the last two and the first two hours of all the 4-hour spells is 8.4. The average loss due to the interruption is roughly 9.[1]

Hence the difference in the ratio equals the loss of time, and the actual uncorrected production of the hours immediately following the recess is about the same in relation to the production of the hours preceding the recess, as without a recess, notwithstanding the loss of time.

The significance of this calculation as a control measure is pointed out in a later section of this chapter, page 198.

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[1] To illustrate: In crank case grinding, evening shift, the figure 49.6 for the third hour represents an actual uncorrected output of 41.3 (49.6=41.3 multiplied by 6/5) and the ratio of the $\frac{\text{third and fourth hours}}{\text{first and second hours}}$ or $\frac{41.3+43.5}{39.8+42.0}$ is roughly 103.4, or 9 per cent less than the ratio 114 (more exactly 113.8) given in the table calculated from corrected output. Where the recess period occurs 3 hours before the end of a spell, this correction of 1 hour will make even less difference.

TABLE 38.—*Effect of recess periods on*

	Number of observations.	Starting time.	Period of study.
Crank shaft grinding (morning shift):			
Without recess	653	7 a. m.	Sept. 15–Nov. 5
Recess at start of fourth hour	575	7 a. m.	Nov. 7–Dec. 22
Difference in ratio due to recesses			
Crank shaft grinding (evening shift):			
Without recess	439	3.30 p. m.	Sept. 15–Nov. 5
Recess at start of seventh hour	577	3.30 p. m.	Nov. 7–Dec. 22
Difference in ratio due to recesses			
Axle grinding (morning shift):			
Without recess	587	6.45 a. m.	Sept. 19–Oct. 13 Oct. 29–Nov. 10
Recess at start of third hour	480	6.45 a. m.	Oct. 15–Oct. 27 Nov. 14–Dec. 7
Difference in ratio due to recesses			
Axle grinding (evening shift):			
Without recess	577	3.15 p. m.	Sept. 19–Oct. 13 Oct. 29–Nov. 10
Recesses at start of third and seventh hours	476	3.15 p. m.	Oct. 15–Oct. 27 Nov. 13–Dec. 8
Difference in ratio due to recesses			
Commutator loom (morning shift):			
Without recess	15	7.30 a. m.	Oct. 23–Nov. 15
Recesses of 5 minutes at start of third and seventh hours	8	7.30 a. m.	Oct. 13–Oct. 22
Difference in ratio due to recesses			
Recesses of 10 minutes at start of third and seventh hours	7	7.30 a. m.	Dec. 5–Dec. 17
Difference in ratio due to recesses			

hourly rate of output, eight-hour plant.

Average output observed each working hour.								Ratios between hours.		
First.	Second.	Third.	Fourth.	Fifth.	Sixth.	Seventh.	Eighth.	4 and 5 / 1–3	7 and 8 / 6	6 and 8 / 1–5
Before lunch.					After lunch.					
22.0 22.8	24.0 24.1	24.4 24.3	24.5 ‖ ¹ 28.3	25.0 ² 24.9	24.6 ³ 25.4	24.3 24.8	23.7 24.4	105 112	98 97	101 100
....	....	....	....	....	....	....	....	7	....	−1
Before lunch.				After lunch.				3 and 4 / 1 and 2	7 and 8 / 5 and 6	5–8. / 1–4.
22.7 23.9	23.2 24.8	23.5 25.1	23.3 25.6	23.9 25.4	23.8 25.2	24.0 ‖ ¹ 28.2	23.0 23.6	102 103	99 102	102 104
....	....	....	....	....	....	....	....	....	3	2
Before lunch.					After lunch.			3–5 / 1 and 2.	7 and 8 / 6	6–8 / 1–5.
45.0 42.7	48.6 46.0	49.6 ‖ ¹ 53.2	48.4 48.3	⁴ 53.0 ⁴ 45.9	⁵ 49.6 ⁵ 50.4	49.3 47.0	44.2 38.2	107 111	94 85	98 96
....	....	....	....	....	....	....	....	4	....	−2
Before lunch.				After lunch.				3 and 4 / 1 and 2.	7 and 8 / 5 and 6.	5–8 / 1–4.
46.4 45.8	48.3 47.9	49.5 ‖ ¹ 54.3	49.7 48.9	53.0 49.9	49.3 42.4	48.6 ‖ ¹ 54.3	42.0 40.9	105 110	89 103	99 95
....	....	....	....	....	....	....	....	5	14	−4
Before lunch.				After lunch.				3 and 4 / 1 and 2.	7 and 8 / 5 and 6.	5–8 / 1–4.
763 957	871 1,051	871 ‖ ¹1,081	⁴ 896 ⁴1,019	856 1,029	845 1,058	835 ‖ ¹1,096	⁵ 776 ⁵ 1,023	108 105	95 102	97 102
....	....	....	....	....	....	....	....	−3	7	5
651	713	‖ ¹ 775	⁴ 801	723	750	‖ ¹ 790	⁵ 732	116	103	102
....	....	....	....	....	....	....	....	7	8	5

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[1] Output corrected for recess period. The mark ‖ indicates the position of the recess, which is placed either at the bdginning or at the end of the hour.

[2] Period of ½ hour; actual output multiplied by 2.

[3] Period of 1½ hours; actual output divided by 3/2.

[4] Period of ¾ of an hour; actual output multiplied by 4/3.

[5] Period of 1¼ hours; actual output divided by 5/4.

TABLE 38 (Continued).—*Effect of recess periods*

	Number of observations.	Starting time.	Period of study.
Rear axle housing (morning shift):			
Without recess	598	6.45 a. m.	Sept. 14–29
Recess at start of third hour	222	6.45 a. m.	Oct. 16–26
Difference in ratio due to recess			
Rear axle housing (evening shift):			
Without recess	469	3.15 p. m.	Sept. 13–Oct. 13
Recesses at start of third and seventh hours	200	3.15 p. m.	Oct. 15–Oct. 26
Difference in ratio due to recesses			
Crank case grinding (morning shift):			
Group A:			
Without recess	26	7 a. m.	Sept. 19–Sept. 29
Recesses at start of second and seventh hours	151	7 a. m.	Oct. 15–Dec. 22
Difference in ratio due to recesses			
Group B:			
Without recess	43	7 a. m.	Oct. 1–Oct. 13
Recesses at start of third and seventh hours	99	7 a. m.	Oct. 15–Dec. 22
Difference in ratio due to recesses			
Crank case grinding (evening shift):			
Groups A and B combined:			
Without recess	90	3.30 p. m.	Sept. 19–Oct. 13
Recesses at start of third and seventh hours	228	3.30 p. m.	Oct. 15–Dec. 22
Difference in ratio due to recesses			

on hourly rate of output, eight-hour plant.

Average output observed each working hour.								Ratios between hours.		
First.	Second.	Third.	Fourth.	Fifth.	Sixth.	Seventh.	Eighth.	3–5 1 and 2.	7 and 8 6.	6–8 1–5.
Before lunch.					After lunch.					
17.9 18.5	19.2 18.8	19.6 ‖ [3] 21.4	20.1 19.7	[1] 22.8 [1] 22.3	[2] 18.1 [2] 19.6	19.9 19.0	19.3 19.5	112 113	108 98	96 96
								1	−10	0
Before lunch.				After lunch.				3–4 1 and 2.	7 and 8 5 and 6.	5–8 1–4.
18.8 18.1	20.1 18.9	20.2 ‖ [3] 21.9	20.6 21.0	21.4 20.4	20.7 20.8	19.7 ‖ [3] 22.1	19.4 19.6	105 116	93 101	102 104
								11	8	2
Before lunch.				After lunch.				2–4 1.	7 and 8 5 and 6.	5–8 1–4.
[4] 40.2 [4] 39.8	46.1 ‖ [3] 53.3	46.8 43.5	46.0 42.4	[5] 44.3 [5] 40.7	[5] 44.3 [5] 40.7	45.0 ‖ [3] 51.2	44.8 43.2	115 117	101 116	100 98
								2	15	−2
								3 and 4 1 and 2.	7 and 8 5 and 6.	5–8 1–4.
[4] 42.1 [4] 35.8	44.5 36.9	48.2 ‖ [3] 45.5	46.2 38.5	[5] 43.8 [5] 36.8	[5] 43.8 [5] 36.8	48.6 ‖ [3] 45.7	48.2 39.2	109 116	110 115	102 101
								7	5	−1
38.3 39.8	42.1 42.0	44.2 ‖ [3] 49.6	40.4 43.5	39.3 41.4	41.8 41.5	41.6 ‖ [3] 48.8	42.2 42.9	105 114	103 111	100 100
								9	8	0

[1] Period of ¾ of an hour; actual output multiplied by 4/3.

[2] Period of 1¼ hours; actual output divided by 5/4.

[3] Output corrected for recess period. The mark ‖ indicates the position of the recess, which is placed either at the beginning or at the end of the hour.

[4] Period of 1½ hours; actual output divided by 3/2 to reduce to rate for one hour.

[5] Period of 1½ hours; actual output multiplied by 4/3 to distribute equally over two hours.

EFFECT ON TOTAL DAY'S OUTPUT.

Notwithstanding the increase in the hourly rates of output immediately following the recesses at the 8-hour plant the total production for the whole day was not maintained, even in cases in which the rate of output rose. In three out of four operations studied, the day's output declined after recesses were introduced, although in two cases, rear axle housing and crank case grinding, the loss in output was about proportionate to the loss of working time (Table 39). For the decline, various cogent reasons may be advanced, which are stated below.

Marked differences in response to the recesses are found among the workers here as at the 10-hour plant. Thus in one operation, rear axle housing, only 6 out of 14 workers improved in the two weeks with recesses. One man, No. 206, gained nearly 7 per cent, while another, No. 18, at the same work and during the same period of trial lost 24 per cent. The average daily loss per worker was 3.4 per cent.

In crank shaft grinding, 12 out of 17 men not only maintained their output but showed gains during the seven weeks of the experiment. The average increase per worker was 2.64 per cent. It is worthy of note that this operation, in which the day's output increased after the introduction of recesses, was the only one in which chairs were provided for the men to sit down in during the break.

Two other processes, axle grinding and crank case grinding, showed a marked fall in output, averaging per worker more than 4 and 5 per cent, respectively.

TABLE 39.—*Effect of recess periods on total daily output, eight-hour plant.*

Check No. of worker.	Machine No.	No recesses.		With recesses.		
		Number of observations.	Average daily output.	Number of observations.	Average daily output.	Per cent change.
		Sept. 17-29.		Oct. 15-26.[1]		
Rear axle housing:						
336	6	10 M[2]	170.8	10	168.8	− 1.2
323	13	10 M	173.4	9	152.9	−11.8
289	15	9 M	191.2	9	182.0	− 4.8
230	19	10 M	131.5	6	132.1	+ 0.5
206	10	9 M	164.7	10	176.0	+ 6.9
198	5	9 M	178.9	10	166.1	− 7.2
165	4	9 M	169.7	10	172.0	+ 1.4
90	18	8 M	187.3	10	180.2	− 3.8
46	18	8 M	145.5	10	154.3	+ 6.0
18	3	10 M	168.9	8	128.2	−24.1
508	8	8 E[2]	170.9	8	147.4	−13.8
375	5	7 E	171.1	10	178.0	+ 4.0
371	12	6 E	157.5	6	155.1	− 1.5
312	6	8 E	166.0	7	168.3	+ 1.4
Average per worker						− 3.4

[1] One recess on morning shift; two on evening shift.

[2] M=morning shift only; E=evening shift only.

TABLE 39 (continued).—*Effect of recess periods on total daily output, eight-hour plant.*

Check No. of worker.	Machine No.	No recesses.		With recesses.		
		Number of observations.	Average daily output.	Number of observations.	Average daily output.	Per cent change.
		Sept. 19–Oct. 13.		Oct. 15–Dec. 22, 1917.[1]		
Crank case grinding:						
6082	S[2]	19	358.8	37	332.0	− 7.5
6589	S	11	353.2	31	319.9	− 9.4
6530	S	15	331.5	47	308.9	− 6.8
6277	S	16	318.1	36	312.2	− 1.9
6422	D[2]	10	383.4	6	365.7	− 4.6
5955	S	5	286.5	18	309.5	+ 8.0
5955	D	8	361.5	8	293.7	−18.8
6477	D	18	337.3	5	354.3	+ 5.0
6390	D	19	340.6	23	361.8	+ 6.2
6410	D	16	389.4	50	326.5	−16.2
Average per worker						− 4.6
		Sept. 15–Nov. 5.		Nov. 5–Dec. 22, 1917.[3]		
Crank shaft grinding:						
2614		12	200	25	190	−5.0
2685		34	198	29	199	+0.5
2702		24	216	32	237	+9.7
2716		25	199	30	193	−3.0
2853		18	182	27	190	+4.4
2883		26	204	34	200	−2.0
2895		16	177	14	187	+5.6
3055		17	183	26	197	+7.7
3058		33	200	23	208	+4.0
3082		28	198	35	191	−3.5
3092		30	174	30	188	+8.0
3105		28	192	32	195	+1.6
3136		22	209	35	214	+2.4
3170		25	193	33	202	+4.7
3212		15	172	8	177	+2.9
3219		31	190	30	205	+7.9
3268		31	207	33	205	−1.0
Average per worker						+2.64
		Sept. 19–Oct. 13 and Oct. 29–Nov. 10.		Oct. 15–27 and Nov. 14–Dec. 7, 1917.[4]		
Axle grinding:						
4318		32	410	27	391	− 4.6
4356		26	398	23	379	− 4.8
4419		31	407	33	370	− 9.1
4370		19	387	9	361	− 6.7
4354		29	390	21	364	− 6.7
4342		28	377	20	346	− 8.2
4003		8	381	15	397	+ 4.2
4182		9	380	23	365	− 4.0
4200		32	413	29	395	− 4.4
4223		29	394	18	380	− 3.6
4238		29	307	35	316	+ 2.9
4465		22	401	7	386	− 3.7
4289		26	406	7	411	+ 1.2
4282		6	374	8	360	− 3.8
4402		17	391	6	314	−19.7
4215		31	392	24	367	− 6.4
4220		27	400	26	357	−10.7
4361		28	402	23	380	− 5.5
4392		31	411	25	387	− 5.8
4232		29	416	30	368	−11.5
4287		33	347	30	305	−12.1
4350		33	428	34	398	− 7.0
4395		30	408	32	388	− 4.9
4452		30	399	20	394	− 1.3
4426		24	425	26	407	− 4.2
4276		28	392	15	362	− 7.7
4221		22	414	16	399	− 3.6
4373		16	382	10	360	− 5.8
4206		24	370	21	335	− 9.5
Average per worker						− 5.77

[1] Two recesses.

[2] Type of machine; S=single; D=double.

[3] One recess.

[4] One recess on morning, two on evening shift.

SOME REASONS FOR THE DECLINE IN DAILY OUTPUT AT THE EIGHT-HOUR PLANT.

In view of the increased rates of output at the 8-hour plant in the hours immediately following recess periods, is there any reasonable explanation of the lower level of the total day's work in three out of four operations ?

One important reason is shown statistically in Table 40: namely, the marked fluctuation of output in these machine processes, from one fortnight to another, irrespective of recess periods. All the individuals listed in Table 40 had worked at least two months on these operations before the control period and had worked constantly on the same machine, so that variations in output per day can not be attributed to the factor of learning. This is of especial importance, since in many of the operations studied the men were often changed. It was even found that in some processes, especially in rear axle housing, output was affected by the particular machine on which a man worked so that in these operations all records had to be rejected when a man was not constantly on the same machine.

If without recesses, axle grinding, morning shift, drops between October 13 and 29 from 402.4 to 376.1, a similar decline from 401.6 to 376.8 on evening shift in a different fortnight can not be specifically ascribed to the recesses then in effect. Similarly in crank-shaft grinding, before the recesses were introduced there was a fall from 198.2 to 183.3. In the face of such wide variations in the output of given groups of men without recesses, we can not consider these rest periods entirely responsible for the decline in output which in various cases accompanies these machine operations.

TABLE 40.—*Output of given groups of men[1] for consecutive fortnights before and after introduction of recess periods, eight-hour plant.[2]*

REAR AXLE HOUSING.

[Recess 8.45 to 8.55 a. m.; 5.15 to 5.25 p. m.; and 9.45 to 9.55 p. m.]

Shift.	Group and size.	Average daily output per man.								Weighted average.[3]	
		Sept. 19 to Sept. 28.	Oct. 1 to Oct. 13.	Oct. 15 to Oct. 27.	Oct. 29 to Nov. 6.	Nov. 6 to Nov. 10.	Nov. 12 to Nov. 24.	Nov. 26 to Dec. 8.	Dec. 10 to Dec. 22.	Whole period without recess.	Whole period with recess.
Morning.	A (10)	168.0	....	*166.6*	....	....	....	....	....	168.0	*166.6* (163.0)
Evening.	B (4)	166.2	....	*170.5*	....	....	....	....	....	166.2	*170.5* (163.5)

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[1] Groups composed of men whose output is recorded in Table 39.

[2] Output figures which are in italics were produced with recess periods. They are "corrected" for those periods. Uncorrected figures are given in parentheses.

[3] Averages weighted according to number of observations at each period.

TABLE 40 (continued).—*Output of given groups of men*[1] *for consecutive fortnights before and after introduction of recess periods, eight-hour plant.*[2]

CRANK CASE GRINDING.

[Recess (group A) 8.30 to 8.40 a. m.; (group B) 9.30 to 9.40 a. m.; (groups A and B) 1.30 to 1.40 p. m.; 5.30 to 5.40 and 10 to 10.10 p. m.]

Shift.	Group and size.	Average daily output per man.								Weighted average.[3]			
		Sept. 19 to Sept. 28.	Oct. 1 to Oct. 13.	Oct. 15 to Oct. 27.	Oct. 29 to Nov. 6.	Nov. 6 to Nov. 10.	Nov. 12 to Nov. 24.	Nov. 26 to Dec. 8.	Dec. 10 to Dec. 22.	Whole period without recess.		Whole period with recess.	
Morning.	A (4)	352.4	......	*365.0*	......	......	*349.1*	......	*352.4*	362.5	348.5	*336.1*	*337.8* (323.7)
	B (6)	......	369.6	......	*326.8*		......	*320.1*	......			(322.1)	
Evening.	A (4)	......	343.4	......	*355.5*		......	*347.4*	......	335.4		*339.2*	
	B (6)	325.2	......	*349.4*	......	......	*330.8*	......	*333.5*			(325.3)	

CRANK SHAFT GRINDING.

[Recess 10 to 10.10 a. m. and 10 to 10.10 p. m.]

Shift.	Group and size.	Sept. 19 to Sept. 28.	Oct. 1 to Oct. 13.	Oct. 15 to Oct. 27.	Oct. 29 to Nov. 6.	Nov. 6 to Nov. 10.	Nov. 12 to Nov. 24.	Nov. 26 to Dec. 8.	Dec. 10 to Dec. 22.	Whole period without recess.		Whole period with recess.	
Morning.	A (7)	201.4	......	203.1	......	......	*204.8*	......	*207.3*	196.8	194.5	*203.9*	*204.8* (200.6)
	B (10)	......	191.1	......	189.8	*199.5*	......	*200.8*	......			(199.4)	
Evening.	A (7)	......	[4] 201.9	......	206.3	*201.7*	......	*210.8*	......	192.9		*206.0*	
	B (10)	198.2	......	183.3	......	......	*201.4*	......	*206.4*			(201 8)	

AXLE GRINDING.

[Recess 8.45 to 8.55 a. m.; 5.15 to 5.25 and 9.45 to 9.55 p. m.]

Shift.	Group and size.	Sept. 19 to Sept. 28.	Oct. 1 to Oct. 13.	Oct. 15 to Oct. 27.	Oct. 29 to Nov. 6.	Nov. 6 to Nov. 10.	Nov. 12 to Nov. 24.	Nov. 26 to Dec. 8.	Dec. 10 to Dec. 22.	Whole period without recess.		Whole period with recess.	
Morning.	A (16)	401.9	......	*394.0*	......	......	*359.6*	......	......	394.4	394.5	*378.0*	*381.3* (370.2)
	B (13)	......	402.4	......	376.1		......	[4] *366.8*	......			(370.0)	
Evening.	A (16)	......	401.0	......	386.3		......	[4] *366.9*	......	394.7		*386.7*	
	B (13)	396.6	......	*401.6*	......	......	*376.8*	......	......			(370.5)	

[1] Group composed of men whose output is recorded in Table 39.

[2] Output figures which are in italics were produced with recess periods. They are "corrected" for those periods. Uncorrected figures are given in parentheses.

[3] Averages weighted according to number of observations at each period.

[4] Comparatively few observations here.

For this variability of output in machine operations differences in stock are in part responsible. Thus, for instance, in axle grinding the rate of output, which had fallen in a period with recesses, continued to fall in a subsequent fortnight when recesses were abandoned. In the foreman's opinion, the quality of the stock was deteriorating and more time was spent per unit of output in grinding. The fall in output was therefore independent of the recess system.

Another reason for the failure of the workers at the 8-hour plant to maintain output under the recess system seems to have been their efforts to spurt after the recess in order to make up lost time, shown by the increase in rate of output. By thus undoing the benefit of the rest, they reduced the total output for the day.

INADEQUACY OF CONTROLS.

The study of recesses has led us to conclude that the absence of an adequate system of controls is a serious handicap in estimating the effects of recesses upon production. Besides observing the workers in a first control period without recesses there should be observed a second control, namely a group of workers, employed at the same periods, at the same operations and using the same stock, but having no recesses. Such an arrangement, however, comparable to controlled studies in the laboratory, it is difficult to secure in industry. Even if the second group of workers could be observed, working side by side with those having recesses, it is probable that their output would be affected by the propinquity and the distraction attendant upon the experiment of having recesses. The nearest approach to such a control at the 8-hour plant is the calculation on page 188, showing the effect of recesses on the relative production of the hours immediately preceding and following the recess. If it is assumed that the production of the period preceding the recess is not affected by the break, the production of this period is, in a measure, a control for the hours immediately following.

At the 10-hour plant the nature of the operations studied and the fairly constant quality of the stock made these considerations as to the control of less importance. These operations were not machine work, and the human agent had therefore freer scope to show a response to the recess intervals.

2. HOLIDAYS.

Besides the effect of the 10-minute recess another example of the influence of rest on working capacity may be seen after holidays.

It is well established that after the Sunday holiday Monday is commonly a day of low capacity, familiarly referred to in the term "blue Monday." The normal scientific explanation advanced is lack of coordination on Monday due to the relaxation of Sunday. According to this theory, initial difficulty is experienced in recovering the practice acquired in consecutive working days. Punctuality and attendance both suffer on Mondays.

An opportunity of measuring the effect of consecutive holidays was afforded by the 5-day closing order of the Federal Fuel Administrator, January 18 to 22, 1918, inclusive. At that time the production of transmission case rammers was being studied at the 8-hour plant. The average output of six batteries of two men each in the three days immediately before and immediately after the closure is shown in the following table:

	Before closure.		After closure.
Jan. 14	832	Jan. 23	828
Jan. 15	850	Jan. 24	932
Jan. 17	805	Jan. 25	925
Average	829	Average	895

January 23, the first day after the break, is, like Monday after the Sunday break, a day of low output. The benefit of the rest is not apparent until Tuesday.

No wages were paid during the five days' closure, but since wages were on a time basis, the increase in output can not be attributed to speeding in order to make up lost pay.

Attendance also improved immediately after the closure. Absences fell from 7.6 per cent to 4 per cent in the four days after, as compared with the four days preceding the break. But this improvement was due probably as much to the desire to make full-time wages, as to the effects of the rest.

The effect of another holiday—July 4—was observed at the 10-hour plant in the output of seven men employed in the brass finish room. The record of their total output was as follows for the six days beginning June 23 and June 30, 1917.

	June 23–29.	June 30–July 6.
Saturday	7,272	7,405
Monday	6,731	6,912
Tuesday	6,866	6,991
Wednesday	6,949	Holiday.
Thursday	6,883	6,990
Friday	6,974	7,102
Average	6,946	7,080

In the second week there were two breaks, Sunday and Wednesday. The day following was in each case lower in output, but the second day after the break showed a rise. The average daily production during the week of the holiday showed a sensible gain.

CHAPTER 9.

RHYTHM IN INDUSTRY.

In certain machine operations, notably in lathe work, output is maintained at an even level, instead of falling in the final hours of work. This peculiarity may in large part be explained by the phenomenon of rhythm, to which lathe work is highly amenable.

We have seen in an earlier chapter that while there is a distinct fall in output during the working day in all hand processes requiring muscular exertion, dexterity, or attention, there is no appreciable decline in the work of operating machines or feeding furnaces. We may fairly assume that in processes like brazing the speed is to a large extent mechanically maintained by the action of the furnace. Machine work of the lathe type (p. 63) has still to be explained. What enables the operator to keep his pace?

The new element markedly noticeable in these lathe operations which is not observed to any similar extent in either dexterous or muscular handwork is the presence of rhythm, and to this phenomenon of rhythm our investigations ascribe the peculiar stability of output in the lathe-work processes. Rhythm has been described as the "regular and frequent repetition of a group of differentiated motions and pauses." [1]

A typical lathe operation such as spin top cap with its varied and alternating effort lends itself to such regular repetition in a high degree.

The question of rhythm in these machine operations is the subject of an intensive investigation by Dr. P. S. Florence and Dr. A. H. Ryan for the Public Health Service, begun in March, 1918, and still in progress. This investigation will be fully reported in a later publication, but in view of its importance in explaining the maintenance of output in lathe work, a preliminary statement of its findings has been included, by courtesy of the investigators, in the present report.

To establish the presence of rhythm and to compare its degree in different operations, the investigators have used an automatic rhythmometer, which records the workers' motions by electrical contacts on a kymograph, or recording drum.

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[1] Use of Factory Statistics in the Investigation of Industrial Fatigue. A Manual for Field Research. Philip Sargant Florence. Columbia University Studies in History, etc., Longmans, Green & Co., New York, 1918, p. 112.

A series of records taken on this kymograph of the motions of a lathe operator on a typical fuse operation known as face and score train ring establishes very clearly the repetition of motions at regular intervals, which is the primary feature of rhythm. The train ring is the movable graduated brass ring, screwed between fuse body and top cap, by which the time of the fuse is set, and the object of the operation in question is to cut across the face of this ring, left rough by the casting, and to cut in it concentric grooves. The process of facing and scoring is a good example of lathe work, consisting of four separate details performed on a machine with two cutting tools by the manipulation of a series of more or less heavy levers which must be pushed, pulled, raised, or lowered as need requires. These details are (1) placing the train ring in the revolving "chuck" or holder and clamping it in place; (2) "facing," or taking a cut across its face; (3) "scoring," or cutting the grooves; and (4) unclamping the ring and removing it from the machine.

In the accompanying tracing (chart 38) the regular recurrence of these details is strikingly evident. The marks in the first line show clamping and unclamping, in the second facing, in the third scoring. Whether judged by the eye or measured by the scale of seconds at the bottom of the tracing, the time sequence of the corresponding details is almost mechanically exact and regular. Along with the automatic record of the machine movements shown in the first three lines a record, shown in the fourth line, is taken from a signal magnet, which is used by an observer to note external interferences with the worker. The notations are numbered, and memoranda of the actual causes with corresponding numbers are kept on a separate sheet. Certain variations from regularity may thus be accounted for. All operations showing external interferences are eliminated from the calculations.

THE MEASUREMENT OF RHYTHM.

The degree of rhythm in the corresponding steps of successive operations may be determined by their approximation to the average time of performance in any number of successive operations. For certain reasons, chiefly to avoid giving undue weight to extreme values, the median [1] rather than the arithmetic mean has been chosen as the typical average in all calculations and illustrations that follow.

RHYTHM OF CORRESPONDING STEPS IN SUCCESSIVE OPERATIONS.

The degree of rhythm in the successive motions composing the facing and scoring operation is graphically presented by chart 39, which is based on the records of 25 consecutive operations on the fast re-

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[1] For definition, see p. 89.

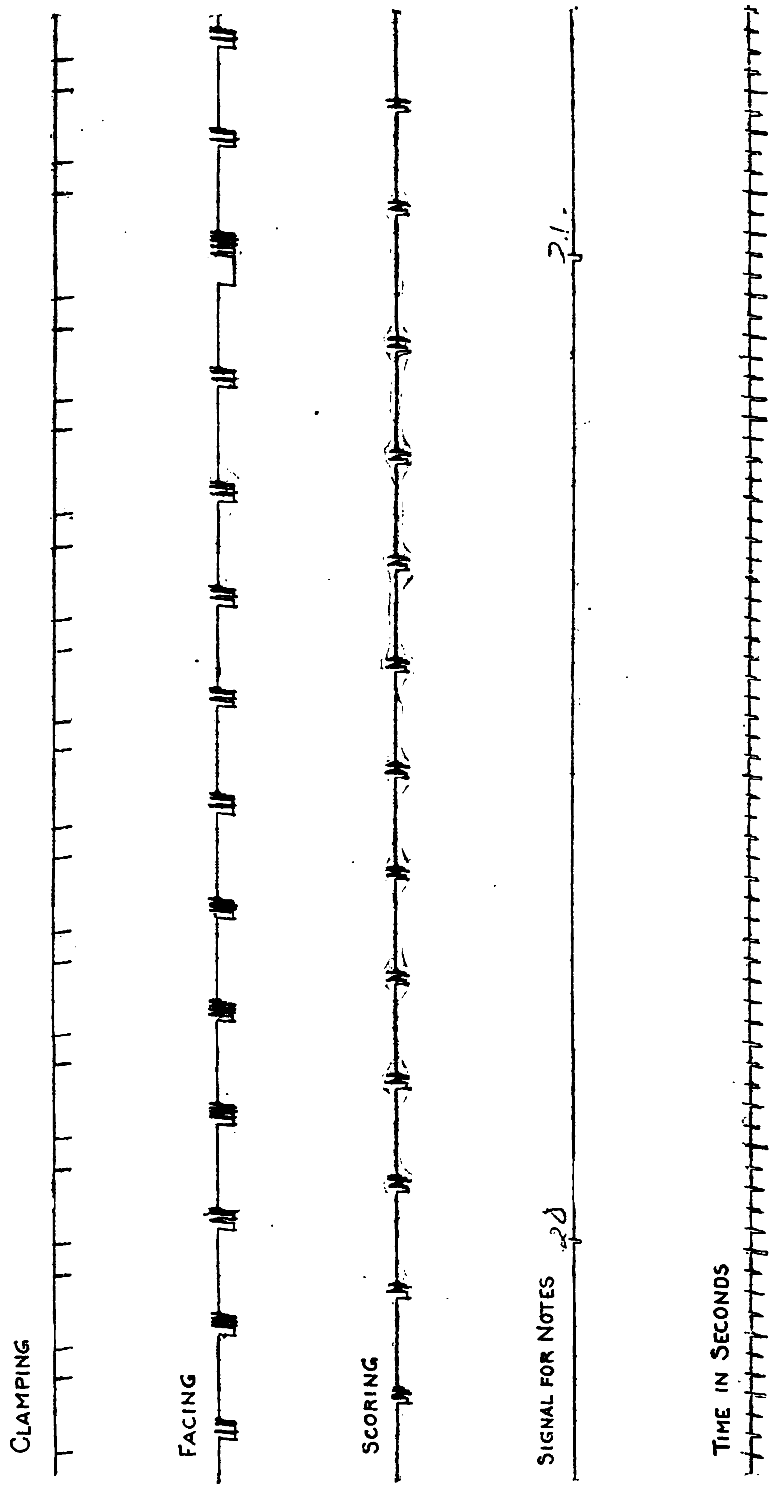
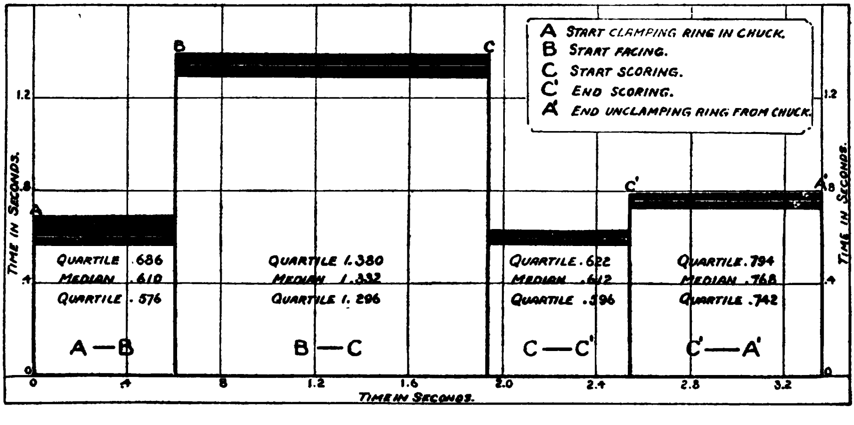


CHART 38.—*Face and score train ring.*

cording drum. For each of the 25 operations the time taken by each step of the process has been obtained from the tracing, and from these figures the median and quartile[1] times for each step have been determined.

The figures in the chart represent the time taken from a certain moment in each step to a certain moment in the succeeding step in the process: A–B, clamping in the train ring; B–C, facing; C–C′, scoring; and C′–A′, unclamping, respectively; the time taken in each case is measured in seconds vertically upward from the base line and on the base line itself. The scale on the base line measures the median time value of the several steps of the operation; the vertical scale measures the median of each of these steps together with the interquartile range[1] of variation. This range is represented by the black bands, the median by the white lines. We thus see that half of the operations in the series fall within the relatively narrow black bands. The relation of the width of each band to the height of the median[2] from the base line measures the comparative rhythm of the step in question. Clearly, the narrower the band as compared with the height of the median, the more regular the rhythm. The most regularly rhythmic detail of the operation, C–C′, shows the lowest variation, probably because it is almost wholly determined by the mechanical contact of tool and material.

CHART 39.—*Rhythm of separate motions within an operation shown by narrowness of range of variation.*



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[1] For definition, see p. 89.

[2] Usually the coefficient of dispersion (see p. 205) is based not on the median but on a point halfway between the two quartiles. This point is not shown on the chart. The median, which approximates to it, has been used (see p. 201).

RHYTHM OF WHOLE OPERATIONS.

The degree of rhythm of entire successive operations may likewise be determined by the approximation of the specific time of performance of one operation to the average time of any number of successive operations. This approximation is shown by chart 40 which presents the results of a much larger number of consecutive operations (300) on the slow recording drum. Here the whole chart represents an entire cycle of the process, from a given step in the production of one ring to the corresponding step in the production of the next, as for example B–B, or A–A.[1] The figures, A–A′ and A′–A, represent the time, respectively, taken by one operation—that is, by the completion of one ring on the machine, and by the interval between operations or between the completion of one ring and the beginning of the next. On the base line the median time value of the 300 operations is shown in seconds for A–A′, A′–A, and B–B, respectively. The vertical scale measures in seconds the time of the median, the interquartile range, and the interdecile range[2] for the entire cycle and the subdivisions given. The black dotted lines represent the median in each case, the black bands the interquartile range, and the shaded bands the limits of the interdecile range. Thus it may be seen that one-half of all the time values of the operations in the series of 300 fell within the range indicated by the black bands and four-fifths of all the time values within the range indicated by the shaded bands. As in chart 39, the relation of the width of these bands to the height of the median from the base line measures the comparative regularity of the cycle or subdivision under consideration.

A STATISTICAL MEASURE OF RHYTHMIC REGULARITY.

An exact mathematical measure of the degree of rhythmic regularity of the facing and scoring operation is presented by the following table (Table 41). This table gives the average percentage deviation from median time of an experienced worker for the entire cycle of the process, for a single operation, and for the interval between operations, observed during three successive days at stated hours. To give an idea of the average time of the operation, column 4 gives the median time in seconds taken by the entire cycle, A–A, or B–B. From this median time the time of each successive cycle may obviously deviate widely. The measure of deviation is obtained by taking the arithmetic mean deviation from the median of all cycles observed in each hourly series each day[3] (sum of separate deviations regardless of signs divided by number of items) and finding what percentage it is of the median. The resulting percentage deviation, also called the coefficient of dispersion, furnishes an exact measure of the rhythm of the cycle. Percentage deviations from the median time of a single operation[1] (A–A′), and of the interval between operations[1] (A′–A), are similarly obtained by calculating the percentage of average deviation to the median time in each case. The smaller the percentage deviation, the more regular is the rhythm. The special point of interest is the remarkably narrow range of deviation through the several days and the fact that on the average the process is not less rhythmical in the evening than in the morning.

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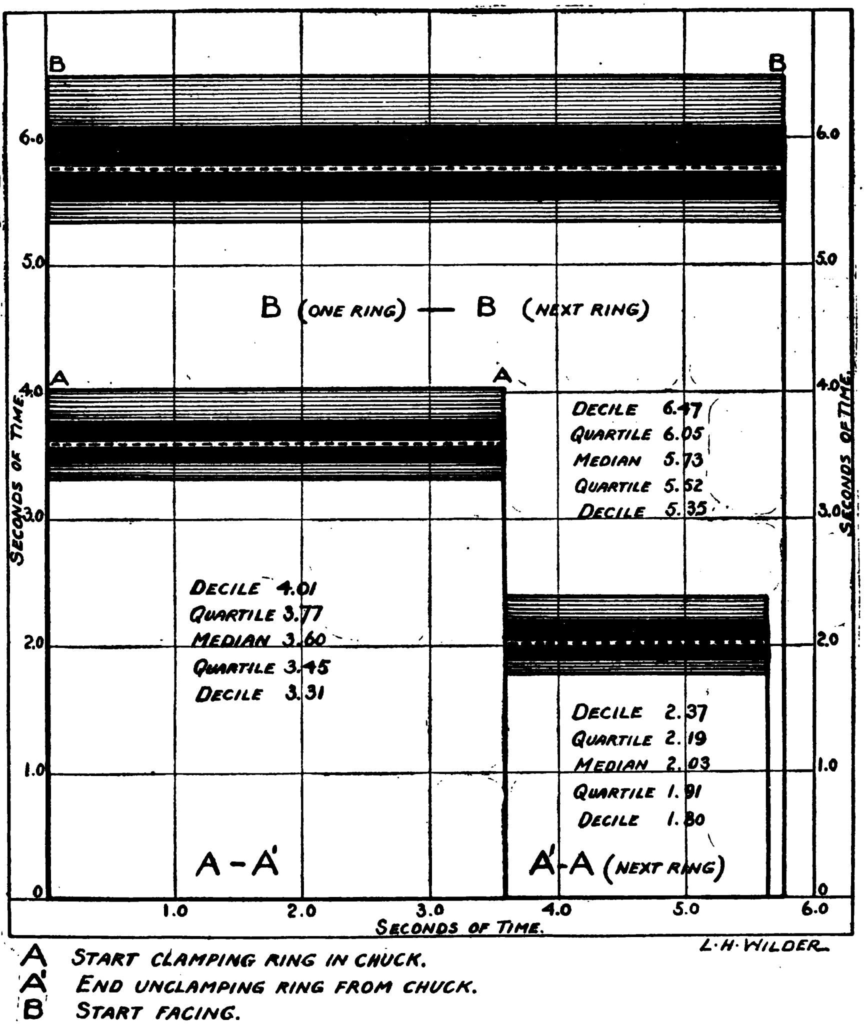
[1] As a matter of convenience in reading the records, the cycle was measured from B to B.

[2] The interdecile range = the range between which four-fifths of all the time values in the series lie.

[3] Not given in the table.

Chart 40.—*Rhythm of whole operation shown by narrowness of range of variation.*



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[1] Not given in Table 41.

TABLE 41.—*Comparative rhythm at different times of day.*

Lathe machine operation: Face and score train ring; operator, E. M.

1918.	Time of day.	Number of operations observed each hourly series.	Cycle of process,[1] median time in seconds, B-B.	Percentage deviation from median time of—		
				Cycle B-B.	Operation A-A.′	Interval A′-A.
Aug. 12	8 a. m.	[2] 178	[3] 4.77	[3] 4.65	[3] 4.72	[3] 8.44
	11.15 a. m.	103	4.55	4.02	3.19	6.49
	1.25 p. m.	121	4.45	4.70	4.44	6.93
	4.48 p. m.	126	4.47	5.66	7.07	6.14
Aug. 13	8.44 a. m.	125	3.78	5.76	6.47	8.36
	11 a. m.	126	4.21	5.65	3.95	9.38
	1.50 p. m.	125	4.24	3.56	3.13	6.24
	5 p. m.	124	3.93	3.31	3.20	6.53
Aug. 14	8.11 a. m.	125	4.39	2.89	3.07	5.52
	11.24 a. m.	102	4.08	3.58	2.74	8.54
	1.31 p. m.	125	4.37	4.71	4.82	8.19
	5 p. m.	125	4.55	3.60	4.02	7.98
Average of three days.	8 to 9 a. m.	....	4.31	4.43	4.75	7.44
	11 to 11.30 a. m.	....	4.28	4.42	3.29	8.14
	1 to 2 p. m.	....	4.35	4.32	4.13	7.12
	4.45 to 5 p. m.	....	4.32	4.19	4.76	6.88

[1] Cycle of process=time taken from a given step in the production of one ring to the corresponding step in the production of the next.

[2] Total of two series.

[3] Average of two series.

COMPARATIVE DEGREE OF RHYTHM IN DIFFERENT PROCESSES.

The rhythmical character of lathe work in comparison with other types of work is made strikingly evident by Table 42. Here the rhythms of two examples of lathe operations, face and score train ring and bevel train ring, are compared with an example of foot-press work (muscular type) on the one hand, and on the other with a control formed by a simple repeated action designed to obtain a high degree of rhythm, namely, tapping on a tambour. Comparison of the percentage deviations shows the approximation of the experienced lathe operators to the control to be very remarkable. The example of muscular work, on the other hand, though the operator selected had an experience of twelve years, showed a deviation more than twice as great as that of the best lathe operators and almost four times as great as that of the control.

TABLE 42.—*Comparative rhythm of different operations.*

Operation.	Operator.	Number of hourly series averaged.	Number of operations included.	Cycle of process,[1] median time in seconds (B-B).	Percentage deviation from median time of—			Remarks.
					Cycle B-B.	Operation A-A.′	Interval A′-A.	
Face and score train ring	E. M.	[2] 12	1,505	4.32	4.34	4.24	7.40	Experienced; steady.
	Mrs. Q.	5	513	4.92	6.35	5.93	10.87	Experienced.
Bevel train ring	Mrs. T.	2	195	6.71	4.47	5.56	....	Experienced; slow.
Foot press assembly	Mrs. P.	2	209	2.52	9.23	....	....	12 years on job.
Tapping on tambour.	R.	1	184	....	2.54	....	....	Investigator.
	Mrs. P.	1	100	....	2.40	....	....	Foot-press operator.

[1] Cycle of process = time taken from a given step in the production of one ring to the corresponding step in the production of the next.

[2] Average of all series appearing on Table 41 at different times of day.

These tables and charts may be considered to establish (1) the presence of rhythm in lathe operations, and (2) the highly rhythmical character of lathe work as compared with other types of work. Does this new element of rhythm offer any clue to explain the peculiar maintenance of output in this type of production? No one who has observed skilled and unskilled workers on the lathe machine can fail to be impressed with the greater apparent ease with which the work is performed by the skilled worker. No direct proof that the rhythmic manner of working postpones fatigue is as yet available. A postponement might indeed be expected in the rhythmical worker or operation as a result of working throughout the day at a more uniform pace. It is well known that a worker, when unpracticed, always complains of more fatigue than later when he has learned the operation.

Table 43 shows the rhythm of an inexperienced operator, M. D., on the facing and scoring operation, as compared with that of two experienced operators, E. M. and Mrs. Q. The grades of efficiency of these three workers are clearly indicated by the comparative speed of the three in performing the whole cycle of the process (B–B). For this whole cycle the median time of the best worker, E. M., was 2.03 seconds less than that of the learner, M. D., and 0.60 seconds less than that of the medium worker, Mrs. Q. These figures, however, give the median times of series of records of very different degrees of deviation, as is shown by the percentage deviations in the next column. The percentage deviation of the learner is 7.21 for the entire cycle; that of the medium worker, 6.35; and that of the best worker, 4.34. This lesser deviation of the best worker holds good also in the case of the whole operation (A–A′)[1] and of the interval between operations (A′–A).[1] It is clear that the rhythm is least good in the inexperienced worker, M. D. It is also seen that of the experienced workers the one, E. M., giving a higher output is more rhythmical. While Mrs. Q. was equally experienced, her output was less; her daily output was less consistent; and, it may be added, the quality of her work was not so good.

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[1] Percentage deviations are calculated as before from the median time and the average deviation therefrom. In each case $\frac{\text{average deviation from median}}{\text{median time.}}$ = percentage deviation. These medians and average deviations are not given in the table.

The fact that the experienced and slower worker was less rhythmical and the faster, experienced worker more rhythmical suggests a reduction of fatigue by rhythm.[1] This does not mean, as we shall see later, that a rhythmical operation may not be very fatiguing, more fatiguing, indeed, than a factory operation of a different character.

TABLE 43.—*Rhythm of different operators on the same operation.*

Operation.	Operator.	Number of hourly series averaged.	Number of operations included.	Cycle of process, median time[1] in seconds (B–B).	Percentage deviation from median time of—			Remarks.
					Cycle, B–B.	Operation, A–A′.	Interval, A′–A.	
Face and score train ring.	E. M....	[2] 12	1,505	4.32	4.34	4.24	7.40	Experienced; steady.
	Mrs. Q..	5	513	4.92	6.35	5.93	10.87	Experienced.
	M. D....	3	298	6.35	7.21	7.15	12.26	Learner.

[1] Median time given for purposes of illustration for B–B; median time for A–A′ and for A′–A not given in table.
[2] Average of all series appearing on Table 41 at different times of day.

But the probable effect of rhythm in reducing fatigue will be taken up at length in the special report on rhythm soon to be published. The more immediate concern of the present chapter is its apparent power to mask fatigue and to enable an operator in spite of it to keep an unvarying pace throughout the day. These are facts of common knowledge, new only in their application to the industrial world. In exercises permitting of steady rhythms the performance is no criterion of the fatigue involved; the work done is done at the same pace, even after prolonged effort. An adjustment to rhythm may enable a lathe worker to keep up production, precisely as the regular swing of an oarsman's body carries him through the last hour of a fatiguing day.

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[1] The practical relation of rhythm to efficiency is clearly suggested in the Interim Report of the British Health of Munition Workers Committee on Industrial Efficiency and Fatigue (1917, p. 12):

"Good individual output is often the result of escape from fatigue by conscious or unconscious adoption of particular habits of manipulation or of rhythm."

A later page of the same report (p. 77) has a striking comment on the possible value to production of the better coordinated activity resulting from skilled instruction of the workers:

"The committee think it strange that while soldiers are sedulously instructed both in drill movements, which are indirectly, and in rifle and bayonet exercises, which are directly of value to them in carrying out their duties in the field, munition workers, not less important contributors to our national defence, have to depend upon casual and haphazard information, or may be referred to technical schools which, however excellent, can no more replace factory instruction than can drilling in the park training in the field; and have noted that, though in the athletic world instructors exist to teach boxers how to balance themselves and use their arms, and cricket professionals are constantly at work improving the efficiency of batsmen and bowlers, and coaches are a necessity to teach a boat's crew collectively and individually how and when to move their bodies and hands, yet in the industrial world the value of teaching operatives how to earn their livelihood is hardly yet recognized. * * *

"The Committee feel no doubt that just as the athlete obtains further incentive to skill by seeking information as to his faults from a trained teacher, so should operatives be able to turn for instruction as to wasteful and non-productive practices unconsciously developed, and as to methods of improving their work with less effort, and that such teachers would be able to give useful advice to the management as to the most suitable speed for running machinery and as to the best moment to choose for rest pauses."

To find out whether fatigue actually present is masked in the output curve by rhythm it is necessary, then, after determining that the degree of rhythm in a given operation is as great in the evening as in the morning,[1] to apply tests for fatigue at the end of the day and compare the degree of fatigue in such a rhythmical operation with that occurring in operations of non-rhythmical character, in which the output curve falls during the day. As a measure of fatigue the vascular skin reaction test of Ryan was experimentally applied in the present investigation.

This test consists in making a light stroke with a blunt instrument on the skin of the forearm and measuring by stop watch the time from the moment of stimulation to the beginning of the fading of the white streak that presently appears. The time required for this vascular skin reaction, designated fading time, was uniformly found to be decreased by work and increased by rest. The shortening of this fading time in consequence of work done is clearly evidenced at the end of the morning spell and still more marked at the end of the day. The difference in the fading time in the evening from that in the morning is believed to be an index of the fatigue incurred through the day's work.

The accompanying table (Table 44) shows by percentage fall from morning to evening the varying degrees of fatigue recorded by this test on lathe operators as compared with operators on various other types of work. Two of the operations studied, dial press and fuse assembly, show a fatigue fall in the output curve; in lathe work, where the singularly steady maintenance of output gives no appreciable evidence of fatigue, the vascular skin reaction shows a heavier degree of fatigue in women than any other operation studied. Next in order of fatigue shown by this test come the drilling and reaming operations,[2] next to these dial press, and last, the lightest type of work studied, namely, fuse assembly.

Assuming the validity of the skin reaction test, now being further studied in relation to industrial work, we are justified by the testimony it offers in concluding that fatigue is present in lathe operations and that, moreover, it is heavier in their case than in any of the other operations studied by this test.

It must, moreover, be pointed out that lathe-machine operators are in general a stronger type of women than the girls on other kinds of work. Not only is an effort made by the employment service to select for the job women physically suited for heavy work, but the "standard strength" or "job strength" as indicated by Martin's test,[3] to which operators tend closely to approximate in a given job, is definitely higher for women in lathe work than that for women on the drilling, dial press, and fuse assembly operations. This difference is made strikingly evident by Table 44.

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[1] See p. 205. [2] Drilling and reaming were not included in the output study. [3] For explanation, see p. 46.

TABLE 44.—*Fatigue of lathe operators and operators on other types of work.*

Operation.	Number of observations.	Average per cent fall[1] morning to evening vascular skin reaction.	Standard strength as determined by muscle-strength test.
Lathe machines:			
Fuse body, third operation	20	29.60	2,260
Delay retard carrier	24	29.00	1,921
Percussion plunger	29	28.17	1,744
Bevel train ring[2]	24	27.90	1,927
Average	97	28.67	1,977
Drilling and reaming	120	26.14	1,717
Dial press	63	25.25	1,533
Fuse assembly	127	24.52	1,747

[1] Obtained by dividing the average decrease in seconds in fading time in the evening as compared with the morning by the average morning time in seconds.

[2] Large size.

The excess fatigue shown then by the lathe operators over operators on other types of work would probably be very much greater if we were able for purposes of comparison to transfer the bench workers to the lathes.

SUMMARY.

In the present stage of the investigation of rhythm, the following conclusions, in so far as concerns the bearing of rhythm on the output curve, may reasonably be drawn:

1. Lathe work exhibits a high degree of rhythm, and is more rhythmical than other factory work studied in this report.
2. Rhythm is maintained in lathe work till the end of the day in spite of the fatigue apparently indicated by physiological tests. Rhythm, therefore, seems to mask the fall of working capacity.
3. The output curve in lathe work does not, therefore, give a true indication of the course of working capacity, and its maintenance toward the end of the day may well be ascribed not to the absence of fatigue but to the phenomenon of rhythm described in this chapter.[1]

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[1] Another explanation of the sustained productivity of lathe work suggests itself in connection with chapter 3 on lost time and especially with the table on p. 79. In the operation of spin top cap at the 10-hour plant the time lost involuntarily during the day, it will be recalled, was one and a half hours; the time lost in starting and stopping three-quarters of an hour more. This great amount of lost time may largely account in this operation for the absence of any appreciable fall in working capacity. While time spent waiting is often associated with irritation, the reduction of actual work to 7¾ hours may reasonably be expected to react beneficially on working capacity.

But while the recuperative effect of lost time may serve as an explanation for the level production of the later hours of spin top cap, it will not cover the case of the only other unsterotyped lathe operation studied at the 10-hour plant, face and score train ring. This process shows a comparatively small amount of lost time in the course of the day (38 minutes), but exhibits the typical lathe-work curve. Still less does the explanation of lost time fit the lathe operations at the 8-hour plant.

RELATED PUBLICATIONS.

Available reprints and bulletins on industrial sanitation issued by the Public Health Service.

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[1] Not reprinted as yet because of lack of funds.

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